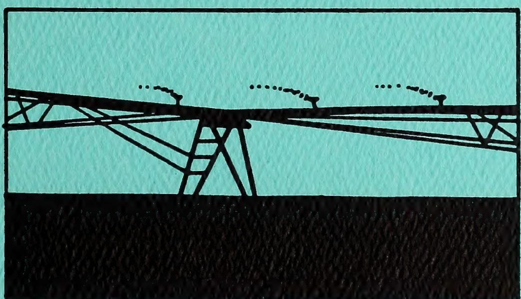
IRRIGATION AND RESOURCE MANAGEMENT DIVISION



Applied Research Report 1992 - 1993

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

1992-93

APPLIED RESEARCH REPORT

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

ALBERTA AGRICULTURE, FOOD AND RURAL DEVELOPMENT

April, 1993

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PREFACE

The Irrigation and Resource Management Division Annual Applied Research Report is a collection of progress and final research reports. The research is carried out by staff members of the Division and private consultants retained under contract. Research projects vary from detailed tests to field surveys; from irrigation to conservation topics.

The reports are limited in length and summarize the highlights. The detailed data and information is available from the individual researchers. The reports have been grouped according to subject matter. The authors are responsible for the contents of the report.

Copying of the material is permitted provided credit is given to the researcher(s) and the data and interpretations are not altered.

ACKNOWLEDGEMENTS

I would like to thank the staff members who carried out the research and prepared the reports in this 1992-93 edition of the Applied Research Report of the Irrigation and Resource Management Division. I acknowledge the great effort to plan and carry out these projects. I appreciate also the encouragement and support provided by their supervisors. On behalf of all, I thank the farmers, the Irrigation Districts and Agricultural Service Boards for their cooperation.

In particular, I thank Dawn Gara, Hank VanderPluym and Barb Shackel for compiling the Report.

Brian L. Colgan
Director
Irrigation & Resource Management Division

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

APPLIED RESEARCH REPORT - 1992-93

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SOIL SALINITY AND SODICITY LEVELS ON LANDS IRRIGATED FROM VERDIGRIS LAKE RESERVOIR

K. M. Riddell[1]

INTRODUCTION

Verdigris Lake is a man made reservoir developed in a glacial meltwater channel in southern Alberta. The reservoir covers about 790 ha. and holds 10,000 acre ft. of water.

Approximately 850 ha. of land are irrigated with water from Verdigris Lake which has an electrical conductivity (EC) ranging from 0.3 dS m^{-1} at the inlet (north end) to 1.6 dS m^{-1} at the outlet (south end). Sodium adsorption ratio (SAR) in the water ranges from 3 at the inlet to 6 at the outlet.

Electrical conductivity and SAR levels in the water at the inlet end of the Lake fluctuate greatly in response to rainstorms but are generally below safety limits for irrigation water quality (Alberta Agriculture 1983). Water at the lower end and outlet of the reservoir is classified as "Possibly Safe" because EC and SAR levels exceed the safety limits of 1.0 dS m^{-1} and 4.0 as outlined in Alberta Agriculture guidelines (Alberta Agriculture 1983).

Long-term irrigation has the potential to salinize the soil profile if adequate leaching water is not applied or internal drainage is poor. The greater the salt concentration in the irrigation water the greater the risk. In addition, the impact of alternate additions of slightly sodic irrigation water and fresh rainwater on soil structure and infiltration rates is not well understood.

In response to these concerns, the Land Evaluation and Reclamation Branch established three benchmark sites to evaluate the long-term impact on soil quality of irrigation with marginal quality water. The sites were selected at the inlet, lower, and outlet locations along Verdigris lake to consider the varying water chemistry in the reservoir. This report documents 1990, 1991 and 1992 soil EC and SAR levels at these benchmark sites.

METHODS

In the fall of 1990, 1991 and 1992 soil samples were taken from both irrigated and dryland areas at each of the three sites (A, B, and D) (Figure 1). All sites were farmed by different landowners, with Sites A and D pivot irrigated and Site B irrigated by either a towable pivot or a sideroll sprinkler system.

Four replicates were established for each of the irrigated and dryland treatments at Sites B and D (Figure 2). Three replicates were established for each treatment at Site A. One of the dryland corners adjacent to the pivot was unavailable because it was used for corrals. Four soil sampling locations, spaced 25 m apart, were established in each replicate (Figure 2).

Soil profiles were sampled in 15 cm depth increments to a depth of 30 cm and in 30 cm increments from 30 to 120 cm. Soil profiles were described at the time of sampling. Soil samples were analyzed for electrical conductivity (EC) and sodium adsorption ratio (SAR) of saturation extracts (Rhoades 1982).

Statistical analyses were done using a split plot analysis of variance (split by time) on EC and SAR data to determine if the treatment (irrigated vs

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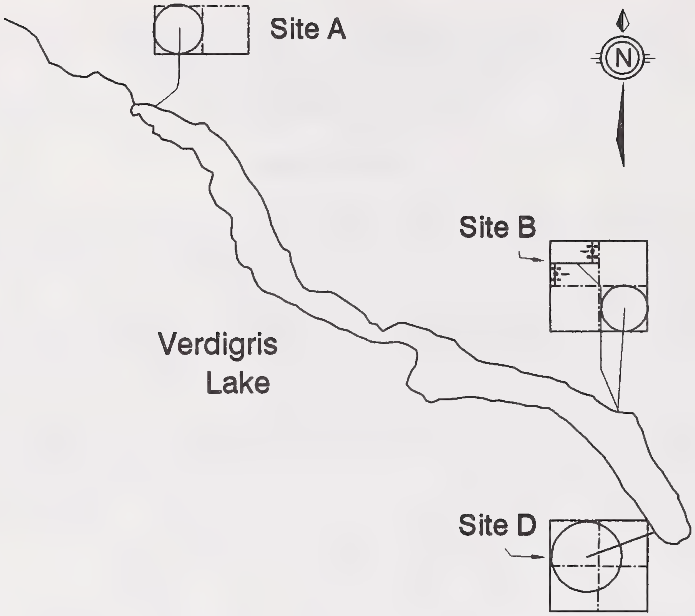

Figure 1. Site location map for Verdigris Lake soil and water quality study.

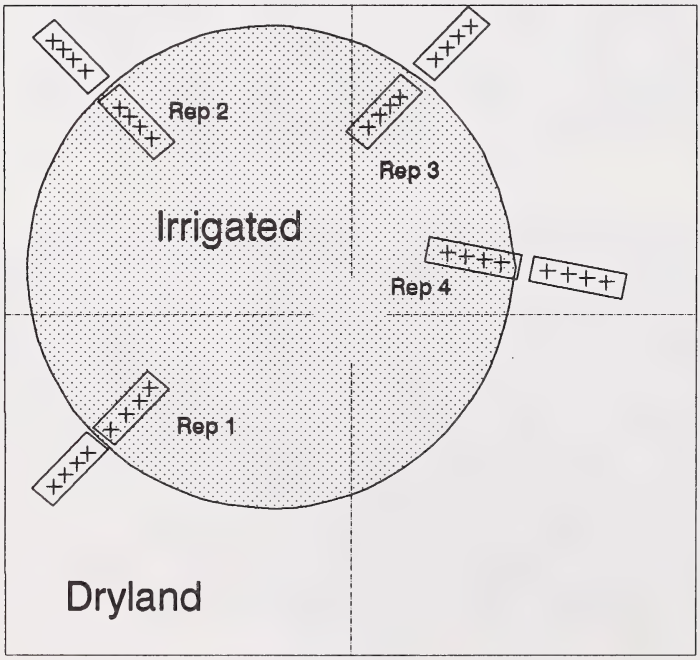

Figure 2. General plan showing replicates and soil sampling locations within replicates at Site D.

non-irrigated), time (1990, 1991 and 1992) or treatment x time interaction effects were significant ($p < 0.05$) for each depth (Gomez and Gomez 1984). Statistically significant main effect and interaction means were compared using Least Significant Difference (LSD) and Tukey tests to determine if mean differences were significant.

RESULTS AND DISCUSSION

Soil Landform

The soil landform at all sites was an undulating till plain with discontinuous veneers of fluvial-lacustrine material overlying the till. Slopes ranged from 2 to 5 % in steepness and 50 to 100 m in length. Soil profiles were dominantly (60-70 %) Orthic Brown Chernozemic with significant (10-20 %) Rego Brown Chernozemic. The dominant soil series at all sites was Masinasin (Kjearsgaard et al. 1984).

Soil EC and SAR

Soil EC and SAR levels in the top 60 cm were higher on irrigated compared to non-irrigated land at all sites (Figures 3 and 4). This increase is statistically significant as confirmed by analysis of variance (Tables 1 and 2) and multiple mean comparisons (data not shown).

Soil EC and SAR levels in the top 60 cm on the irrigated sites was similar to EC and SAR levels in the Verdigris Lake water used for irrigation at each site. At Site A (inlet end of Verdigris Lake), EC and SAR levels in the irrigation water fluctuate between 0.3 and 1.0 dS m^{-1} and 1 to 4, respectively. Soil EC and SAR levels in the upper 60 cm on irrigated land fluctuate between 0.6 to 1.0 dS m^{-1} and 1 to 2, respectively, at this site (Figures 3 and 4).

At Site B (lower end of Verdigris Lake), EC and SAR levels in the irrigation water fluctuate between 0.8 and 1.0 dS m^{-1} and 3 to 4, respectively. Soil EC and SAR levels in the upper 60 cm on irrigated land fluctuate between 0.8 to 1.4 dS m^{-1} and 3 to 4, respectively (Figures 3 and 4).

At Site D (outlet end of Verdigris Lake), EC and SAR levels in the irrigation water fluctuate between 1.2 and 1.6 dS m^{-1} and 5 to 7, respectively. Soil EC and SAR levels in the upper 90 cm on irrigated land fluctuate between 1.3 and 1.7 dS m^{-1} and 5 to 7, respectively.

Soil EC profiles do not show a sequential build up salt on irrigated or non-irrigated sites over the three year monitoring period (Figure 3). Maintenance of soil profile EC levels at irrigation water EC levels indicates that adequate leaching is occurring on the irrigated land. Increased monitoring at the lowest landscape positions is needed to determine the extent of salt redistribution across the landscape.

Statistically significant fluctuations in EC time x treatment means at Site A (Figure 3) are related to changes in irrigation water quality. The highest soil EC in the 0-15 cm depth on irrigated land at Site A was found in the first year of the study (1990) when water quality at the inlet end of the Lake was very poor in May and June.

Comparison of soil SAR levels between years on irrigated and non-irrigated land shows very few changes except at the lowest two depths under the irrigated land at Site D (Figure 4). Statistically significant increases in SAR were found from 1990 to 1992 at the 60-90 cm depth under the irrigated field at this site (Figure 4). This increase is attributed to a number of factors including increased leaching over the monitoring period and possible precipitation of calcium and magnesium at depth. Combined rainfall plus irrigation amounts at Site D increased from 425 to 540 to 627 mm in 1990, 1991, and 1992, respectively.

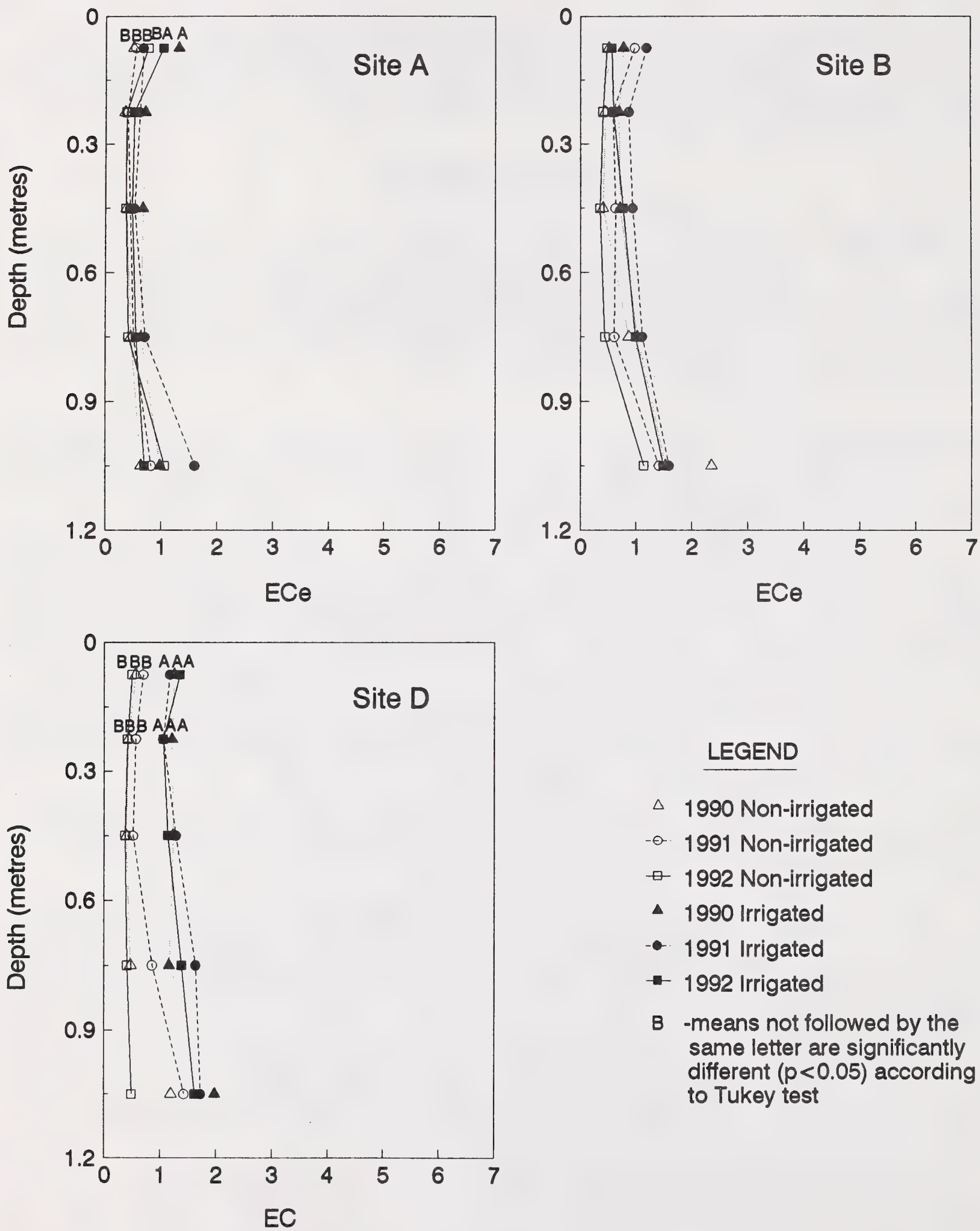

Figure 3. Time x treatment means by depth for Ec on irrigated and non-irrigated treatments (1990,1991, and 1992) at Sites A, B and D.

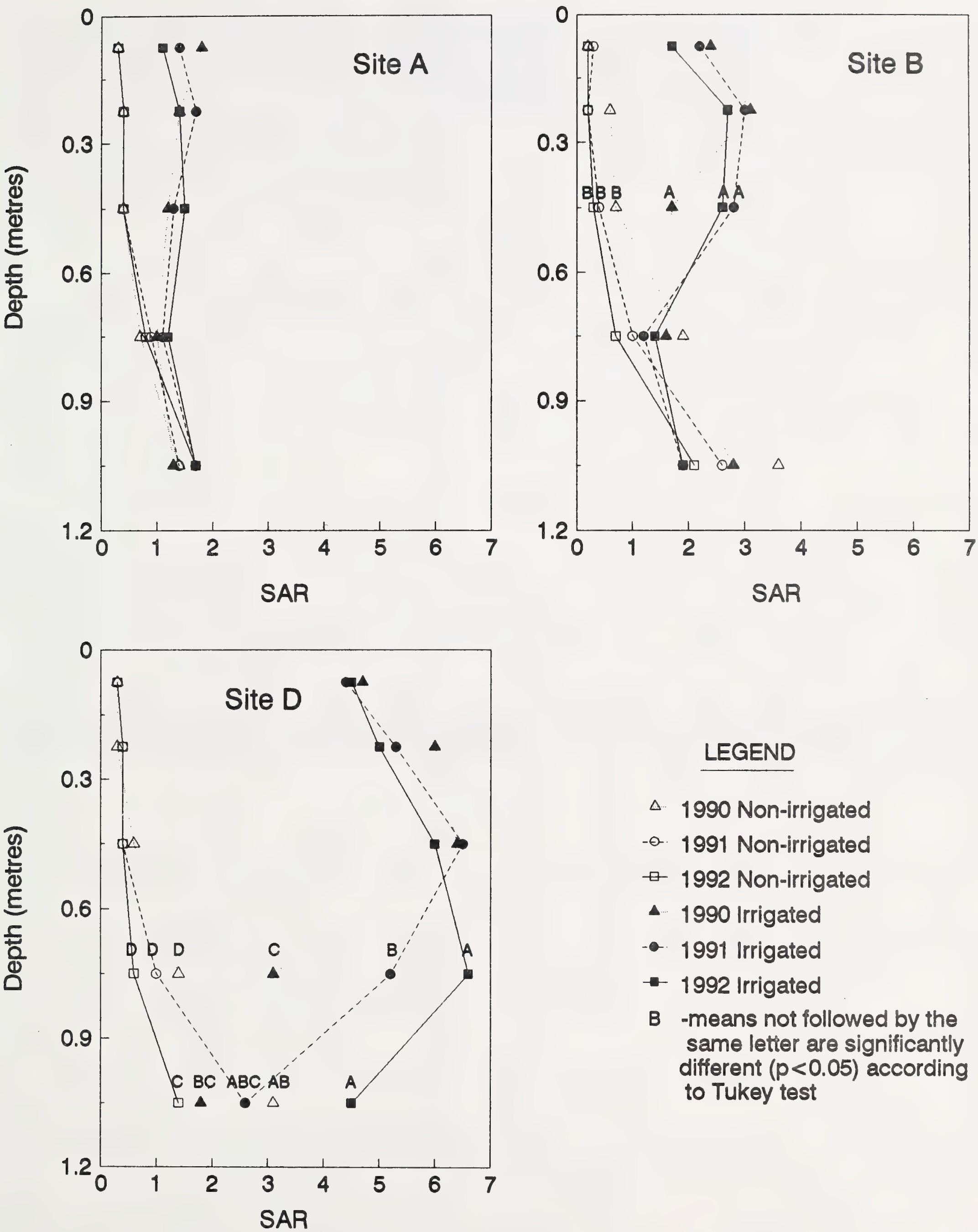

Figure 4. Time x treatment means by depth for SAR on irrigated and non-irrigated treatments (1990,1991, and 1992) at Sites A, B and D.

	Depth	Time	Treatment	Time X Treatment
Site A	0 - 15	.06	.032	.022
	15 - 30	.48	.0033	.23
	30 - 60	.06	.0023	.20
	60 - 90	.10	.035	.93
	90 - 120	.23	.61	.15
Site B	0 - 15	.0001	.085	.62
	15 - 30	.0015	.0093	.92
	30 - 60	.0010	.019	.37
	60 - 90	.25	.026	.29
	90 - 120	.10	.93	.14
Site D	0 - 15	.36	.0001	.0139
	15 - 30	.23	.0001	.0028
	30 - 60	.0025	.0001	.36
	60 - 90	.06	.0003	.43
	90 - 120	.10	.023	.22

Table 1. "F" values indicating level of significance for main effects (Time and Treatment) and interaction (Time and Treatment) from split pH analysis of variance tests done on EC.

	Depth	Time	Treatment	Time X Treatment
Site A	0 - 15	.48	.0001	.15
	15 - 30	.68	.0019	.12
	30 - 60	.12	.0032	.68
	60 - 90	.20	.46	.20
	90 - 120	.57	.94	.96
Site B	0 - 15	.11	.0013	.53
	15 - 30	.12	.0001	.92
	30 - 60	.49	.0004	.0002
	60 - 90	.006	.51	.06
	90 - 120	.011	.60	.81
Site D	0 - 15	.56	.0001	.28
	15 - 30	.78	.0001	.21
	30 - 60	.52	.0001	.93
	60 - 90	.52	.0001	.0004
	90 - 120	.44	.29	.0001

Table 2. "F" values indicating level of significance for main effects (Time and Treatment) and interaction (Time and Treatment) from split pH analysis of variance tests done on SAR.

Soil SAR levels of 4 to 6 in the topsoil on irrigated land could cause potential problems with infiltration during rainstorms. Minhas and Sharma (1986) reported significant reductions in hydraulic conductivity in clay loam soils with an SAR of 5, when soils were irrigated with marginal quality water and subsequently irrigated with rainwater. Curtin et al. (1989) also state that the combined effects of dilution and mechanical effects of a severe rainstorm could cause extensive aggregate breakdown on land irrigated with water of moderately good quality.

CONCLUSIONS

Irrigation with water from Verdigris Lake has caused statistically significant increases in soil EC and SAR in the top 60 cm of irrigated, as compared to non-irrigated, soil profiles at all sites. Increases in soil EC on irrigated land do not exceed the EC of the irrigation water, which ranges from an average of 0.6 dS m^{-1} at the inlet end of the lake (Site A) to 1.4 dS m^{-1} at the outlet end of the lake (Site D). The soil EC levels on irrigated land are below the level of 2 dS m^{-1} at which the yields of very salt sensitive crops might be reduced.

Maintenance of soil EC levels in the root zone (0-1.2 m) at or below the EC levels of the irrigation water indicates adequate leaching is taking place on the irrigated landscape monitored in this study. Additional monitoring at lower landscape positions is required to determine the potential impact of irrigation and runoff on the salinity status.

Increases in soil SAR on irrigated land also reflect the SAR of the irrigation water, which ranges from an average of 2 at the inlet end of the lake (Site A) to 6 at the outlet end (Site D). Soil SAR levels ranging from 4 to 6 in the topsoil on the irrigated land could create potential problems with infiltration during rainfall events and could also make seedbed preparation very difficult at this site if spring rains occur immediately before cultivation.

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RECLAMATION EFFECTIVENESS OF REPLACING LATERAL J-BRID WITH A PIPELINE IN THE SE-35-16-18-W4

K. M Riddell[1]

INTRODUCTION

The Irrigation Rehabilitation and Expansion (IREP) reclamation effectiveness study was initiated to examine the success of various seepage control measures on reclaiming seepage affected land. The study responds to the Coopers and Lybrand report (1987) which raised concerns about the lack of documentation related to reclamation in the irrigation districts. Reclamation is determined by a lowering of the water table followed by a reduction in the soil profile salinity and sodicity to levels which will not affect crop growth.

Previous research into post-canal rehabilitation water table and salinity levels next to canals in the Lethbridge Northern, Raymond, St. Mary River and Taber irrigation districts found that stopping seepage does not guarantee reclamation (Bennett 1990). Water table and salinity levels next to canals are also influenced by surface drainage, local and regional groundwater flow, and internal drainage of soil and geologic materials (Bennett 1990; Millette et al. 1989). Installation of subsurface or surface drainage, changes in irrigation practices and/or control of groundwater recharge may be needed, in addition to canal rehabilitation.

Lateral J in the SE-35-16-18-W4 of the Bow River Irrigation District (BRID) was slated for repair because of problems with seepage and structure deterioration (BRID 1990). IREP # 1539 recommended the canal be relocated and replaced with a pipeline. The project was approved and a pipeline was installed in the winter of 1990/91. This study evaluates the reclamation success of this project by documenting water table and salinity levels in a seepage area before and after canal relocation.

METHODS

Three water-table wells (WTW'S) were installed in a seepage area adjacent to Lateral J on May 1, 1990 (Figure 1). The WTW's were installed to a depth of 4.5 m and were monitored from May, 1990 to Feb., 1993. Monitoring was done every two weeks during the irrigation season and at one week intervals during canal turn on and shut down events. Water-table levels were monitored monthly during the winter.

Soil salinity in the seepage area where the water-table wells were installed was mapped in the fall of 1990 (prior to canal relocation) using the automated EM-38 system. The grid size for the EM-38 map was approximately 10 acres (Figure 1). The EM-38 data was converted to saturated paste electrical conductivity (EC) using equations developed by McKenzie et al. (1989).

Three, 10 x 10 m, soil sampling plots were established in the fall of 1990 (prior to canal relocation) (Figure 1). Soil sampling plots were centered around each WTW and were referenced to permanent benchmarks. Soils at the corners and center of each plot were sampled in 0.3 m intervals to a depth of 1.2 m on Oct. 29, 1990. Soil samples were analyzed for pH, EC, and sodium absorption ratio (SAR) of the saturation extract (Rhoades 1982).

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The EM-38 soil salinity survey was repeated on the same grid in the fall of 1992 (after canal relocation). Soil sampling plots were resurveyed in the fall of 1992 and sampled on Sept. 29, 1992.

There were five soil sampling locations at each of three plots giving a total of 15 soil sampling locations. Mean 1990 (pre-canal relocation) and 1992 (post-canal relocation) soil EC and SAR values (n=15) for each soil sampling interval were plotted on graphs. Mean soil EC and SAR values were compared between years (1990 and 1992) using a paired t-test (n=15) at each depth interval.

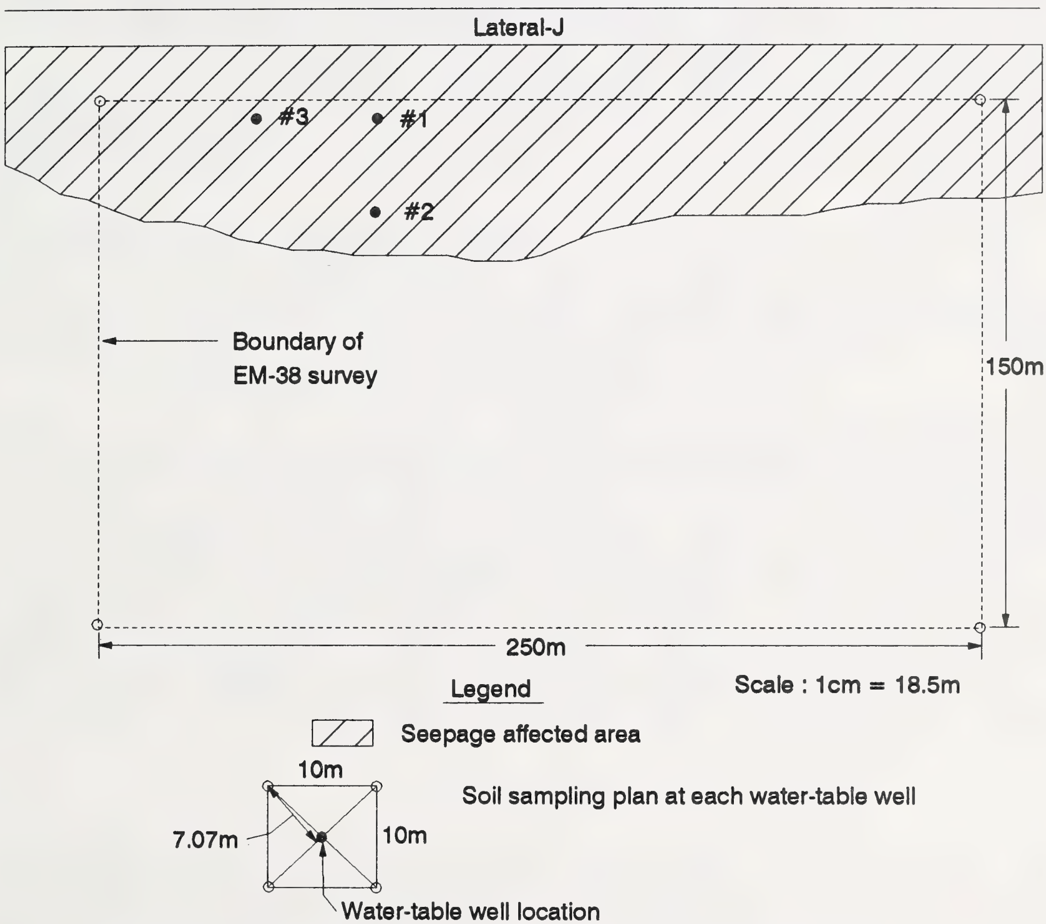


Figure 1. Location plan for EM-38 soil salinity survey, soil sampling and water-table well locations in SE 35-16-18 W4

RESULTS AND DISCUSSION

Soil Landscape

The landscape around the seepage area is a level to gently undulating till plain (Figure 2). The till is saline-sodic throughout the upper 4.5 m, with EC

levels ranging from 7 to 10 dS m^{-1} and SAR levels ranging from 15 to 20. The saline/waterlogged area is slightly upslope of the canal and surface water is directed towards WTW 1, which is in a localized depression (Figure 2).

Soil profiles were classified as Saline-Carbonated-Humic Gleysolic at Plot 1, Saline-Carbonated Brown Chernozemic at Plot 2 and Saline-Solonetzic Brown Chernozemic at Plot 3. The seepage-affected area was covered by kochia weeds (60-70 %) and bare saline salt crusts (30-40 %) prior to canal relocation in 1990. The seepage area was not cultivated in 1991 and was cropped in 1992.

<u>Water Table</u>

The sharp spike on June 5, 1990 on hydrographs for WTW's 1, 2, and 3 coincides with canal turn on and heavy rains which added 70 mm of precipitation during this period (Figure 3). This water table rise is attributed to a combination of canal seepage and recharge from rainfall.

The sharp spike on Sept. 25, 1991 on the hydrograph for WTW 2 was due to fall irrigation (Figure 3). WTW's 1 and 3, which are downslope of WTW 2, were not irrigated in the fall of 1991. The steady rise in water table levels at WTW's 1 and 3 between Sept. 25 and Nov.21, 1991 is attributed to upslope irrigation.

Relocation of the canal in the winter of 1990 has led to a general lowering of water table levels at the two WTW's within 30 to 40 m of the canal (1 and 3), and has had little or no impact on water table levels at WTW 2, which is located 65 m away from the canal (Figure 3). There has been no irrigation over WTW's 1 and 3 since the canal was relocated. The area around WTW 2 was irrigated in 1991.

<u>Soil Salinity (EC) and Sodicity (SAR)</u>

EM-38 salinity mapping showed the acreage of soils having an average profile salinity between 4 and 8 dS m^{-1} decreased from 5 to 2 acres after the canal was relocated (Figure 4). Soil salinity levels declined in the area immediately adjacent to the canal where a general lowering of the water table had occurred.

Results of the EM-38 soil salinity mapping program were confirmed by the pre- and post canal relocation soil sampling which showed statistically significant reductions in average soil EC and SAR between 1990 (pre-canal relocation) and 1992 (post-canal relocation) (Figure 5). Average soil EC levels in the 0-0.3 m depth decreased from 10 to 7.5 dS m^{-1} between 1990 and 1992 (Figure 5). Average soil SAR levels at all depths decreased from above 15 to levels around 12 between 1990 and 1992 (Figure 5).

CONCLUSIONS

Relocating and replacing Lateral J in the SE 35-16-18-W4 with a pipeline has resulted in a general lowering of the water table in a saline/waterlogged area adjacent to the old canal. The drop in the water table has occurred gradually over the two year monitoring period and has been accompanied with slight reductions in soil salinity and sodicity as indicated by EM-38 mapping and soil sampling. The gradual decline in the water table after canal relocation could be due to low hydraulic conductivity in the saline-sodic till.

The seepage affected area is now being cultivated and cropped which should enhance water movement into and through the soil. The area around WTW 1 continues to be a localized depression and will continue to be subject to ponding during storm and irrigation events.

Reclamation is expected to improve in the future if the water table continues to fall and water continues to move through the till under less saline

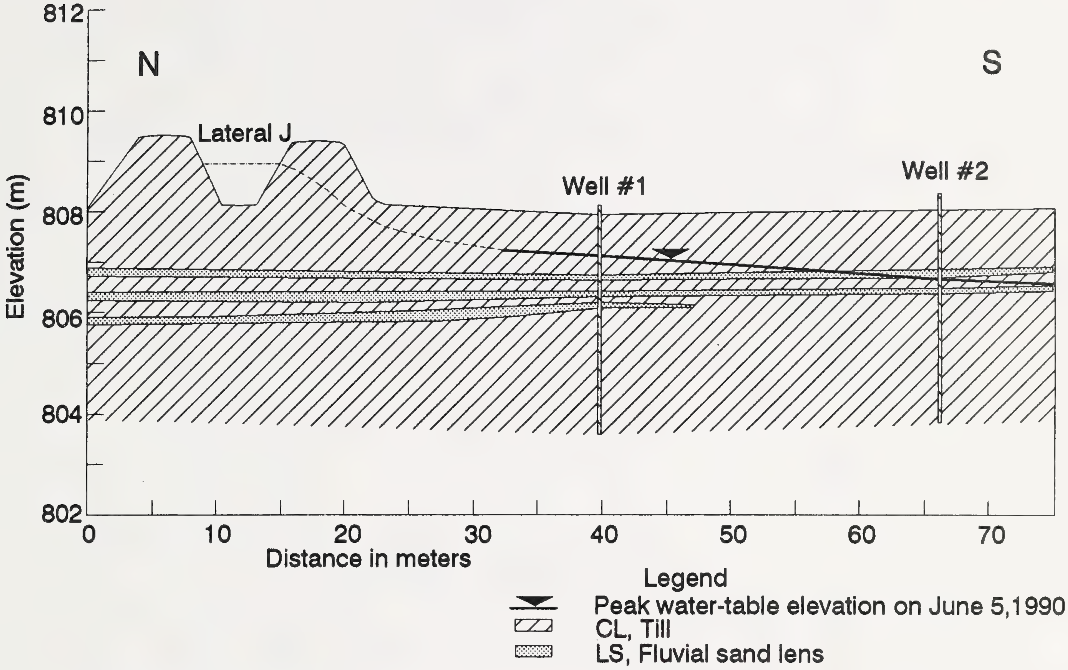


Figure 2. Cross section for seepage affected area.

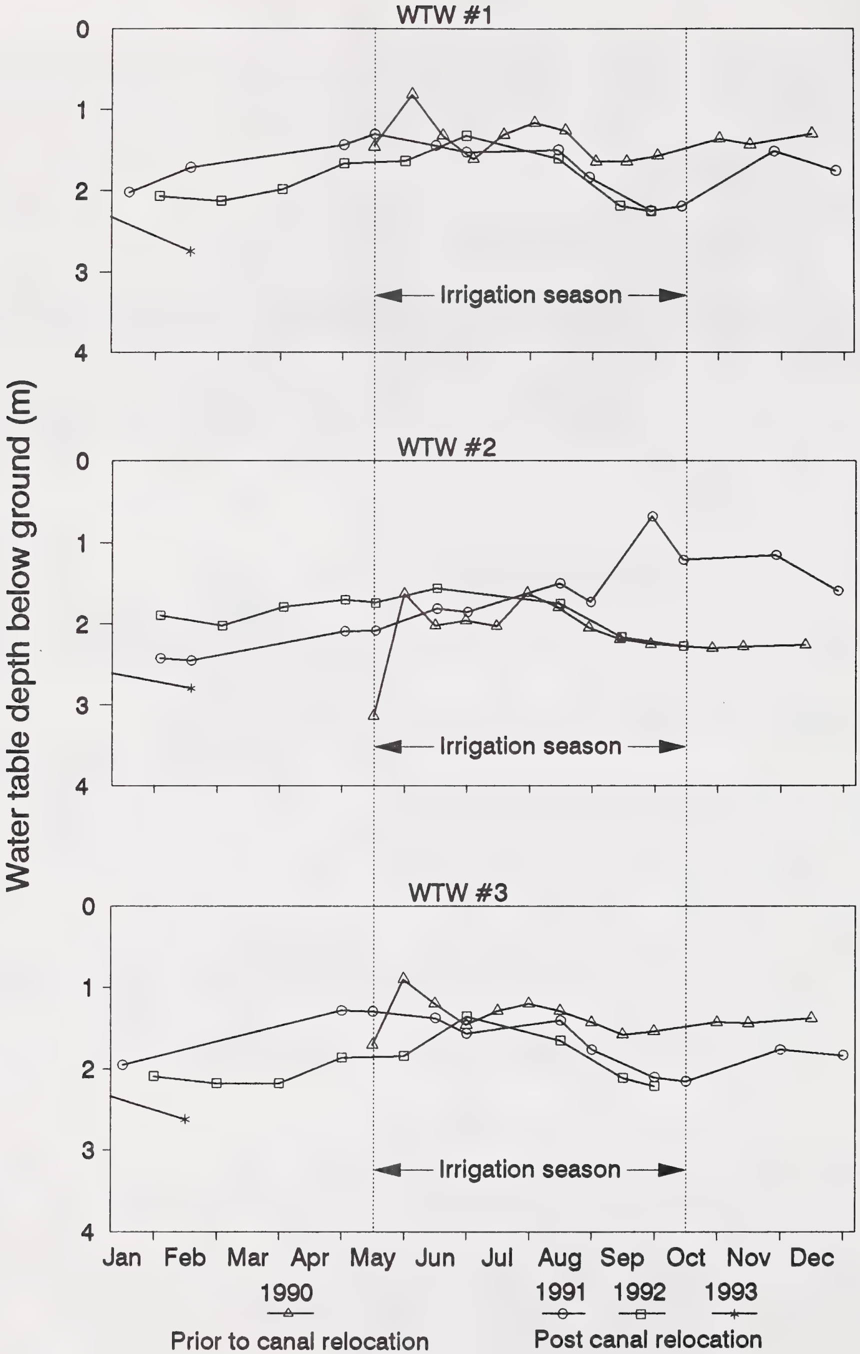
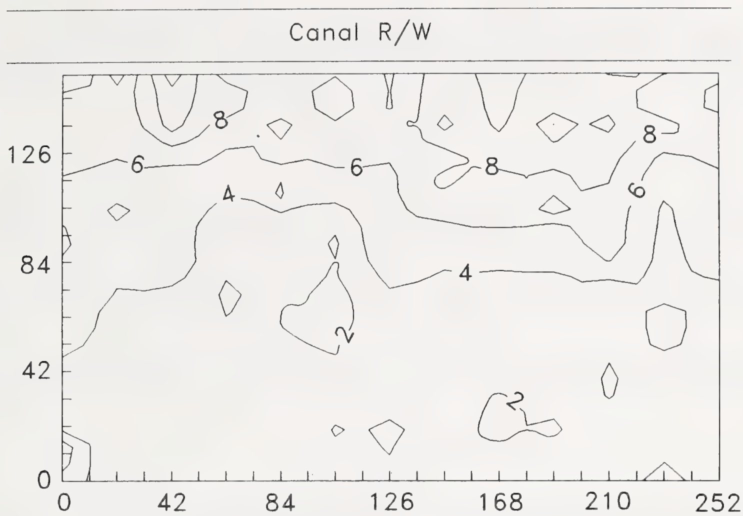


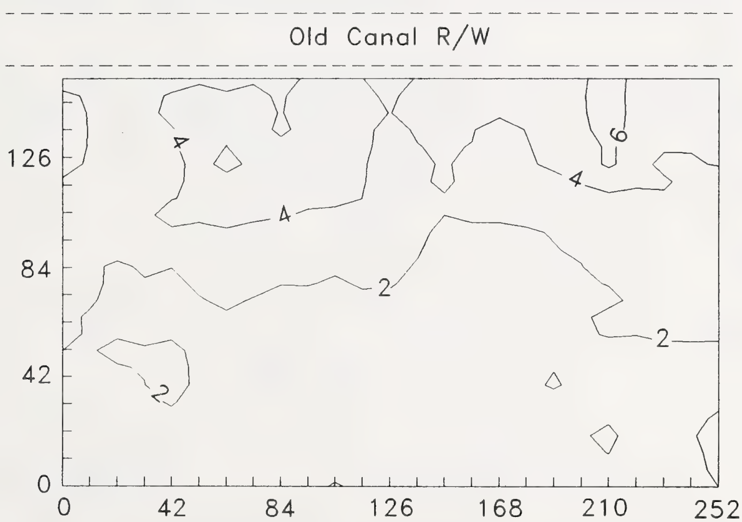
Figure 3. Hydrographs for water-table wells #1, #2 and #3.

Fall 1990 (Prior to Canal Relocation)



(5.25 acres) 0–4 dSm^{-1}
(4.46 acres) 4–8 dSm^{-1}

Fall 1992 (After Canal Relocation)



(7.38 acres) 0–4 dSm^{-1}
(1.88 acres) 4–8 dSm^{-1}

Figure 4. EM–38 salinity map depicting spatial distribution of average profile salinity prior to and after canal relocation.

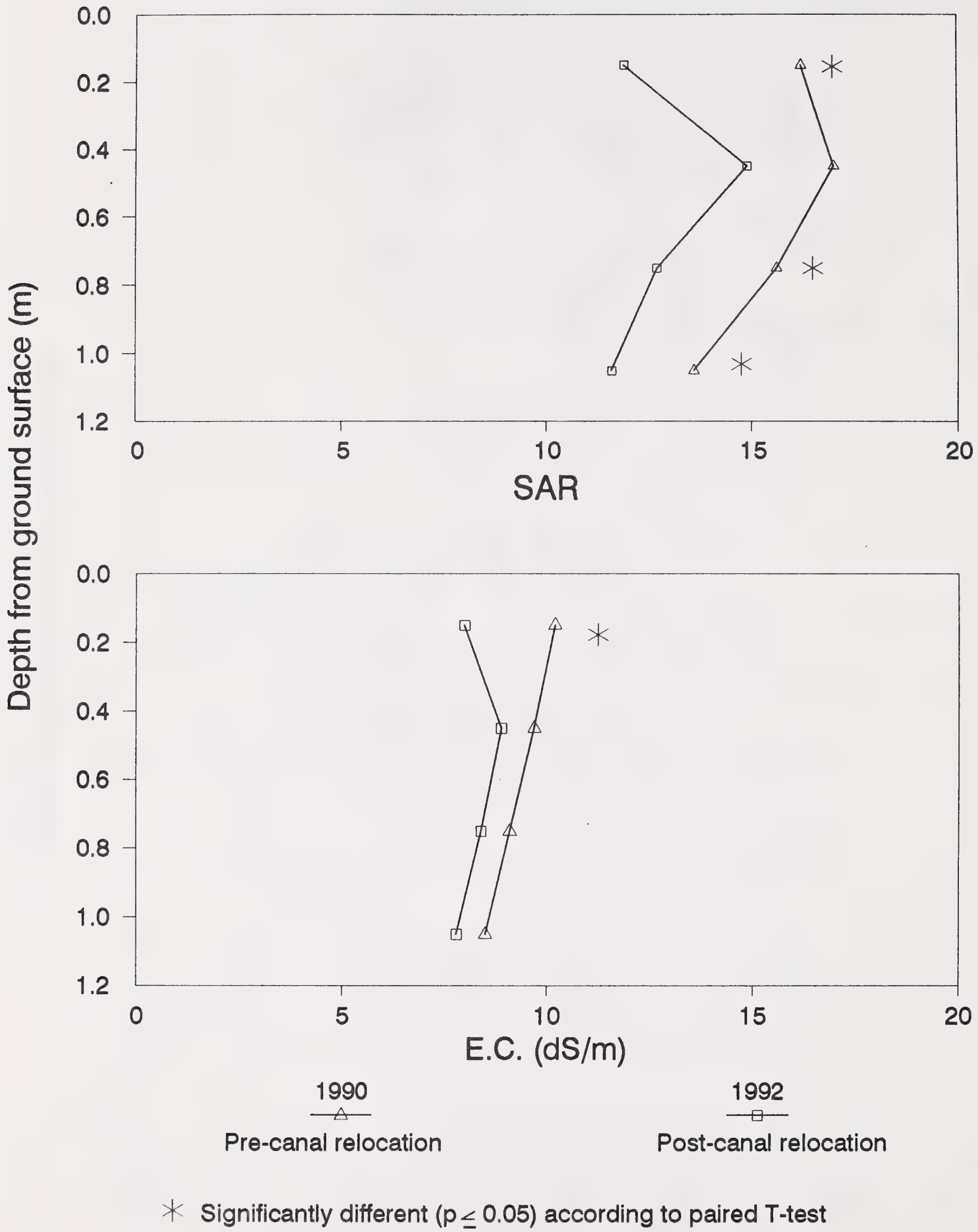


Figure 5. Average EC and SAR values (n=15) vs depth in 1990 (pre-canal relocation) and 1992 (post-canal relocation).

conditions. Desalinization could lead to reduced hydraulic conductivities if sufficient sodium remains and the electrolytic strength of the soil solution is reduced to the point where dispersion occurs.

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DIRECT MOISTURE STRESS MEASUREMENT ON ALFALFA PLANTS GROWN FOR SEED

Gregory Snaith[1] and Dave McKenzie[2]

INTRODUCTION

Growing alfalfa for seed has been largely a hit-and-miss affair, with much fluctuation in yield from one year to the next. These variations are mainly due to weather, specifically temperature and rainfall.

The Irrigated Alfalfa Seed Producers Association of Alberta has determined that its members have benefitted from growing alfalfa under contracts, which are often accompanied by a guaranteed floor price. These types of contracts are granted more readily by the seed companies if they can estimate fairly accurately how many acres to contract in order to obtain the desired quantity of seed.

It is generally accepted that irrigation is the largest contributing factor in determining yield. Moisture stress, which is required to obtain top yields, is presently measured by monitoring soil moisture. Measuring the desired amount of stress directly on the plant would enable a grower to more closely monitor plant condition and subsequently, make an appropriate decision regarding the amount and timing of irrigation.

The intent of this project was to determine if alfalfa growth characteristics exist which accurately indicate the plant's moisture stress level and which can be easily measured by a trained individual. Furthermore, these measurements need to be immediate enough that the grower can utilize them to irrigate in time to maintain flower production.

METHODS

Individual stems were flagged (three to a site) and monitored at weekly intervals by a technician hired for this purpose through a Farming for the Future On-Farm Demonstration project. Sites were chosen at the Alberta Special Crops and Horticultural Research Center (ASCHRC). Measurements were taken of five growth indicators which had potential for demonstrating a correlation with moisture stress. These included: the number of unopened buds, the number of racemes with at least one open floret, the main stem internode length, peduncle length from main stem to first floret and the tripping percentage. Soil moisture was monitored at all sites.

RESULTS AND DISCUSSION

Unopened Buds Visible

The number of unopened buds at the top of the main stem were counted and recorded each week. At the start of flowering, there were between four and seven unopened buds. This number dropped steadily throughout the flowering period, but seemed to remain at one unless the plant became so dry that it could no longer support flowers. Although no actual size measurements were obtained, it was observed that the buds became smaller towards the end of the flowering stage.

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[2] Irrigation Technologist, Alberta Agriculture, Brooks

It is suspected that this signalled either a natural end to the flowering process (the yield potential had been reached) or an unnatural one (ie. insufficient moisture). Therefore, we were reluctant to use this parameter to predict an irrigation.

Racemes With at Least One Floret Open

This information was collected to determine the flowering pattern for alfalfa seed. It was desired that the grower have some idea as to how long each raceme stayed open and how often a new raceme was produced. It was discovered that racemes can be viable for five to 15 days, although we were not able to isolate the conditions which govern this variation. A new raceme was produced every three days, on average. Plants exhibited one to seven racemes open at any time. Most had either four or five racemes open simultaneously at the height of raceme production.

The most useful information garnered from this part of the project was that the plant tended to continue producing racemes as long as there was little pollinating taking place. The plots, which were understocked with bees, had up to 29 racemes. Growers using leafcutter bees to pollinate their alfalfa crop must coordinate the 21 day incubation period required for pupae to hatch with first flower production. Bee incubation is usually delayed in years when cool weather may threaten their survival. Results from this study indicate that growers may not have to be so concerned that postponing bee incubation in cool years will affect seed production, as plants appear to continue producing flowers until their yield potential is realized.

Main Stem Internode Length

Main stem internode length was measured to obtain the rate of main stem growth during flowering. While the rate of growth does slow as moisture stress increases, it does so at an irregular rate. For this reason, we decided not to use this measurement to predict timing of irrigation.

A relationship was observed between initial stem internode length and later lodging of the plant. It was determined by measurements taken later in the year, that pre-flowering internode lengths in excess of 50mm contributed to lodging, particularly if the weather became cool and wet, causing main stem growth to elongate during flower production.

Peduncle Length From Main Stem to First Floret

Peduncle length was measured after the first floret on the raceme was open as growth ceases once this stage has been reached. Initially, peduncle length was thought to be dependent on soil moisture but this relationship was not demonstrated on the plots, except for certain, single plants. Peduncle length did, however, seem to decrease as the season progressed (successive racemes were shorter than previous ones, even on the well-watered plots). A more definitive relationship between peduncle length and soil moisture may result if peduncle length were to be corrected for date, raceme number or other variables.

An optimum peduncle length was observed to be in the 15-25mm range. It is still suspected that moisture is the prime initiator of peduncle growth, but, at present, it cannot be demonstrated.

Tripping Percentage

The tripping percentage was recorded at a few, selected sites in mid-August which is the traditional cut-off for viable seed in our area. Each raceme was

examined for number of florets and subsequent curls (seed pods).

Data was collected for general information only, and will be used as a standard once we turn our attention to this area.

SUMMARY

This project was initiated by the Irrigated Alfalfa Seed Producers Association of Alberta with the intention of gathering information on alfalfa growth which could be used to schedule irrigation and increase yields. Five plant parameters were measured in an attempt to define an indicator which would relate directly to soil moisture status.

There is no single plant measurement which demonstrated a strong correlation with soil moisture. Combining parameters and correcting for date or other external factors may be the only means of eliciting a measurable crop response to soil moisture stress.

IRRIGATION AND SOIL MOISTURE MONITORING
LUCERNE FOODS - PEA CONTRACTS

1992

Gord Cook, Ray Collett[1]

INTRODUCTION

Objectives

Determine the current level of irrigation management for a selected group of processing pea growers.

Collect field data to determine crop consumptive use.

Evaluate different irrigation systems for pea production.

Test an infrared crop canopy temperature device in peas.

Support Lucerne fieldmen and producers in soil moisture level determination and irrigation scheduling.

METHODS

Eleven Stampede variety pea fields were selected for monitoring. These fields were all in the Taber - Cranford area. From seeding to harvest, weekly soil moisture levels were determined by the "feel method". Water applied through irrigation or rainfall was recorded for each field. At the start of each week, field and weather data was delivered to the Lucerne Foods office for the use of company fieldmen.

At the end of the season, available soil moisture levels were plotted, along with the soil moisture holding capacity and the allowable depletion for each field. Yield data was obtained from the company. Total crop consumptive use of water, soil moisture levels and yield were compared.

During the growing season, an Everest infrared ag multimeter was used in several of the pea fields. The multimeter uses solar radiation, relative humidity, ambient temperature, and crop canopy temperature to compute a crop water stress index. This crop water stress index can be used for irrigation scheduling. We also hoped to use this index as a means of estimating crop maturity and harvest schedules.

RESULTS

Alberta Agriculture guidelines recommend soil available moisture levels be maintained above 60% for processing peas. Peas are shallow rooted so moisture levels in the top 0.5 metres of the root zone are most critical. Soil available moisture levels fell below 60% on only a few occasions for some growers. Available moisture never dropped below 50% for any growers in the study group. 1992 was a relatively wet year, but irrigation systems and scheduling appears adequate to prevent any crop losses due to moisture stress.

The average yield for 11 producers was 1458 kg. Four producers were above this average and 7 were below. Table 1 ranks the 11 fields according to yield with their associated consumptive use. The average consumptive use for all growers was 323 mm. The four top growers had an average consumptive use of 329

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mm. The 7 below average producers had a consumptive use of 319 mm. There is no significant difference between these consumptive use figures. It appears that water management was not yield limiting in any of the fields monitored. It is interesting to note that the highest producing field had the lowest consumptive use.

Table 1: Yield and Consumptive Use, 1992.

Yield (kg/ac)	Cu (mm)
1905	276
1805	323 Average CU top 4 growers = 329 mm
1660	366
1515	351
Average Yield	1458 kg/ac
1452	336
1451	300
1442	308 Average CU bottom 7 growers = 319 mm
1334	359
1234	316
1233	335
1007	280

Side roll sprinklers were used on 3 fields and pivots irrigated the remaining 8. There was no evident difference in yield due to irrigation system. The labour requirement for side roll sprinklers is higher than for pivots. This is especially true for peas because of the shallow root zone and lower allowable depletion than for other common crops. Producers were willing to move their side roll sprinklers as often as 6 times per day to apply water as necessary. This level of labour input is not common in other crops, but the high potential value of the pea crop was incentive enough to go to the extra work. The higher application rates per irrigation of side roll sprinklers make scheduling more difficult, especially near harvest. Light applications of water which keep up to crop demands but do not saturate the root zone making harvest traffic difficult are easier to apply with centre pivots. However, all of the producers in the survey group managed to schedule their irrigations properly, regardless of system type.

Some irrigations occurred late in the season in an attempt to delay harvest. Since none of the fields exhibited any moisture stress, it is not clear as to whether this is effective or not. If fields are in need of irrigation, applying water may delay maturity somewhat. If fields are not in need of water, the application of more irrigation water has little effect on crop development. It may, however, cool the crop canopy for a short time and slow maturity.

The infrared gun was not very useful for irrigation scheduling or estimating

crop maturity. Because of the relatively low cost of irrigation water compared to other crop inputs, we recommend that irrigation scheduling should prevent any crop water stress. The infrared gun measures crop water stress. Since none of our monitored fields came under any significant stress, the gun did not provide any useful information. The gun performs best with high ambient temperatures (best above 30°C), clear skies, low RH, and the sun at its highest point in the sky (best between 11:00 a.m. and 2:00 p.m.). The summer of 1992 did not offer this type of weather on a very consistent basis. Peas in general are a short early season crop and most of the irrigation scheduling decisions have to be made before daytime highs of 30°C are common. The gun's weather requirements also make it unreliable as a harvest scheduling aid. Peas are harvested very "green" and no increase in crop canopy temperature was apparent due to maturity before harvest.

CONCLUSIONS

Pea growers appear to implement excellent irrigation scheduling.

Crop consumptive use had little effect on yield in the 1992 study group.

Irrigation to prevent maturity is relatively ineffective if crop is not in moisture stress.

Infrared sensing is ineffective for irrigation scheduling of pea crops in Southern Alberta due to weather requirements and preferred minimum levels of soil moisture depletion.

IRRIGATION AND SOIL MOISTURE MONITORING
LUCERNE FOODS - CORN CONTRACTS

1992

Gord Cook, Ray Collett[1]

INTRODUCTION

Objectives

Determine the current level of irrigation management for a selected group of processing corn growers.

Collect field data to determine crop consumptive use.

Evaluate different irrigation systems for corn production.

Support Lucerne fieldmen and producers in soil moisture level determination and irrigation scheduling.

METHODS

Twenty processing corn fields were selected for monitoring. These fields were all in the Taber - Cranford area. From seeding to harvest, weekly soil moisture levels were determined by the "feel method". Water applied through irrigation or rainfall was recorded for each field. At the start of each week, field and weather data was delivered to the Lucerne Foods office for the use of company fieldmen.

At the end of the season, available soil moisture levels were plotted, along with the soil moisture holding capacity and the allowable depletion for each field. Yield data was obtained from the company. Total crop consumptive use of water, soil moisture levels and irrigation method were compared.

RESULTS

Alberta Agriculture guidelines recommend soil available moisture levels be maintained above 50% for processing corn. Soil available moisture levels never fell below 50% for any growers. 1992 was a relatively wet year and irrigation demand was quite low.

No yield data was compared for the 20 corn fields monitored. Eight fields were left unharvested due to frost damage. Several more fields suffered from poor emergence due to difficult seedbed preparation. The Taber area recorded 1765 Corn Heat Units in 1992. This is only 80% of the expected minimum total of 2200 for our area. As a result of these factors, crop consumptive use figures are relatively low. The average consumptive use of the 12 fields harvested is 387 mm. This is only 75% of the expected consumptive use of 510 mm.

Corn fields were irrigated by three different methods. Nine fields were irrigated with centre pivots. Five fields were irrigated by wheel lines exclusively. Six growers use wheel line sprinklers for early season irrigation and then furrow irrigate the corn crop once it becomes too tall for passage of the side roll sprinkler system.

No fields suffered for moisture in 1992 due to an abundance of

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precipitation. An analysis was performed on the fields irrigated by wheel lines only to determine the risk due to potential late season moisture stress. On these 5 fields, soil available moisture at the time of the last possible irrigation was used as a starting point. This last irrigation generally occurred in the first week of August. From this starting point, a simulated soil moisture curve was created assuming no rain fell from the time of the last irrigation until harvest. Crop consumptive use was determined by the Jensen-Haise method using 1992 weather data. All fields used in the simulation would have experienced significant moisture stress before harvest.

The degree of potential moisture stress is dependent on the level of available moisture following the last irrigation, the soil moisture holding capacity, and the weather. On soils with low moisture holding capacity, the problem is more severe. The simulated crop moisture use was based on 1992 weather, which was generally cool. Total expected crop moisture use as calculated by the Jensen-Haise method from August 10 to harvest was 121 mm.

If no precipitation were to fall during the time period used, temperatures would be expected to be higher than those experienced in 1992. Therefore, crop consumptive use would also be expected to be higher than that determined for 1992. Alberta Agriculture guidelines show corn moisture use under average weather conditions to be 190 mm for the period from August 10 to September 20. This long term average expected consumptive use would put any corn crop, grown on any soil type, under severe moisture stress without supplemental rainfall.

Many of the fields monitored had very poor stands. Some of the corn fields were irrigated prior to final seed bed preparation and some were seeded into a dry seedbed and irrigated to promote emergence. It appears that the better stands in our study group were found on fields that were irrigated before seeding. This is probably due to being able to prepare a firmer and more uniform seedbed in moist soil following a light irrigation. Irrigation immediately following seeding to promote emergence can cause crusting of the soil surface which further reduces plant emergence.

CONCLUSIONS

Corn growers appear to implement excellent irrigation scheduling.

There were no apparent differences in the levels of irrigation management for the three different irrigation methods used in 1992.

Irrigation of corn by side roll wheel lines only exposes the crop to considerable risk of moisture stress late in the season. Timely rains are necessary to prevent crop moisture use exceeding soil available moisture stored in the root zone. The risk is greater on sandy soils with low available moisture holding capacity. No soil type can store enough available moisture to prevent stress for a corn crop which receives no precipitation from the first week of August until harvest.

Irrigation before seeding is recommended if proper seed bed preparation is hampered by dry soil conditions.

CONSUMPTIVE MOISTURE USE OF IRRIGATED ALFALFA

Robert Riewe, P.Ag. and Vincent Ellert[1]

INTRODUCTION

In order to properly manage the irrigation of alfalfa, it is necessary to know the daily consumptive use of the crop. The data that has been traditionally used in Alberta was developed several years ago by Agriculture Canada in Lethbridge. It is not fully understood how this data accounts for changes in crop uses caused by cutting. Multiple cutting is necessary to obtain maximum economic yield. For these reasons, a study was initiated with the following objectives:

1) To determine the crop water use between cutting periods.
2) To verify current consumptive use data of alfalfa under normal field conditions.

METHODOLOGY

In consultation with local alfalfa growers, one representative site was selected in each of 14 fields. All stands of alfalfa were between two and three years old. One 2 metre long aluminum access tube was installed at each site. Soil moisture levels were measured by a neutron moisture probe (Campbell Pacific Model DR531). At the time the access tube was installed, soil samples were collected from each 25 cm increment for textural analyses.

Textural analyses were carried out using the Gee & Bauder method[3]. Field capacity and wilting point were determined by applying the formula developed by Oosterveld & Chang[5] to the texture of the soil. The neutron probe readings were converted to mm of water for comparison with field capacity and wilting point.

Neutron probe readings were taken on a weekly basis starting as soon as the access tubes were installed. Beginning with the first cutting, probe readings were taken every Monday, Wednesday, and Friday. Neutron probe readings continued until October 1.

Other data recorded included rainfall and irrigation dates and amounts. The date, crop stage (% bloom, etc.) were also recorded during the field visits. Stand appearance, variety, inoculation, fertilization, yield information, and other cultural practices were recorded. Data analyses considered the moisture use between each field visit.

RESULTS

Seasonal consumptive use results were very different than what was expected based on past experience (Figure 1). The season started out very hot and dry. The combined precipitation for April and May in Lethbridge was 60 mm less than normal. The dry soil moisture conditions caused very slow growth, resulting in low consumptive use on some sites until the farmer was able to irrigate. Soil moisture conditions averaged 40% of available moisture in the top 1.0 m of the root zone.

Most cuts of alfalfa were delayed due to the unusual cool and rainy weather

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(Figure 2). On some sites, the period between swathing and removal of bales was as high as 28 days. In total, it was a very difficult year for alfalfa production.

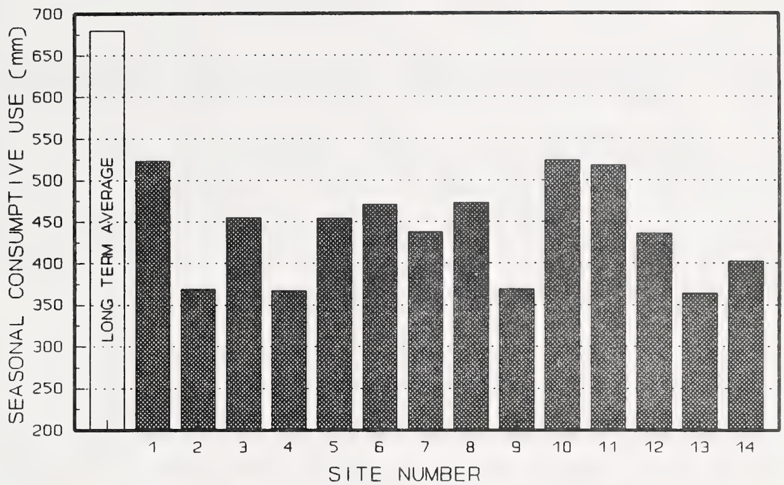

Figure 1. Seasonal Consumptive Use of Alfalfa Lethbridge Area, 1992.

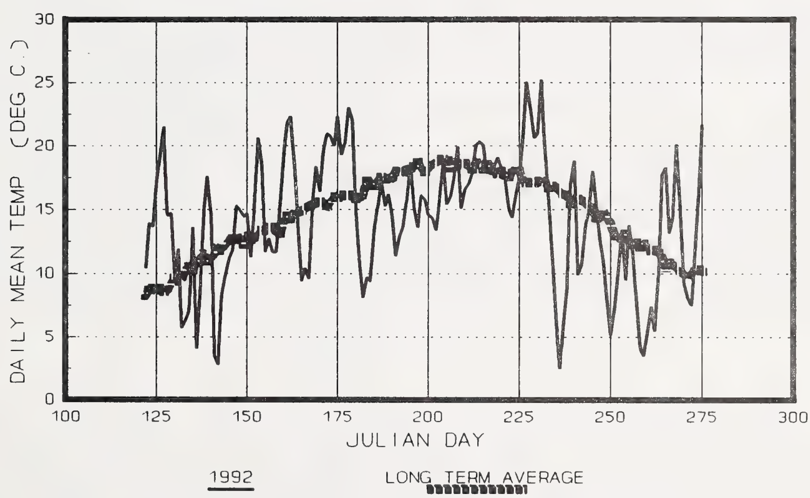

Figure 2. Mean Daily Temperatures, Lethbridge - 1992

Calculating consumptive use between harvest periods was attempted, but results were very erratic. This is attributed to the unusual weather patterns of 1992, which were not representative of a typical alfalfa production season. No results are presented here.

The initial plans were to continue this study in 1993 and 1994. Due to the 1992 season, it is now proposed that data from 1995 will be required to make reliable conclusions.

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FALL IRRIGATION STUDY - 1992

R. Riewe P.Ag., B. Handerek[1]

INTRODUCTION

The purpose of this report is to examine the effects of varied fall irrigation applications on spring soil moisture conditions within a one metre root zone.

Increased fall irrigation application amounts showed higher resulting spring soil moisture levels but corresponding increases in irrigation water lost to evaporation and/or deep percolation. A 55 mm irrigation application raised spring soil moisture conditions within a 0-50 cm soil depth while 125 mm of fall irrigation increased spring soil moisture within the entire one metre zone.

METHODS

The time frame for the study is the overwinter period from final fall irrigation to spring seeding. In this instance, the project's seasonal duration was October 1,1991 to April 1,1992.

The project is located in the S.E.1/4 of 2-10-21-W4, approximately 10 km north of Lethbridge. The plots were situated on soft wheat stubble using a randomized plot design. Four different treatments were replicated three times. The size of each plot was 6.1 m x 6.1 m (20'x 20') with a 9.15 m (30') buffer zone around each plot.

The irrigated treatments consisted of 55 mm application of water, 77 mm, and 125 mm. An non-irrigated treatment is included as a check. Irrigation water application was measured by means of a Tru-chek rain gauge located at ground level in the center of each plot.

Temperature, precipitation and sunshine hours information was obtained from Agriculture Canada at Lethbridge.

Prior to plots being fall irrigated, 1.5 m long aluminum access tubes were installed centrally in each plot. Using a Campbell Pacific neutron probe, soil moisture readings were taken at 25 cm intervals to a depth of 1.5 m. The 100-150 cm depth was monitored for possible deep percolation of soil moisture beyond the 0-100 cm zone. Soil moisture monitoring was done on a weekly basis during late fall and early spring and as weather or field conditions permitted during winter.

RESULTS

The winter of 1991-1992 was warmer and drier than the recorded normals for the Lethbridge area (Table 1). During this over winter period, there were 146 days (82%) that had maximum day time temperatures greater than 0°C and 57 days (32%) with minimum day time temperatures greater than 0°C. There were 28 days (16%) that had day time temperatures greater than 15°C. Over winter precipitation for this time period is on average 119.4mm. In 1991-92, the plot area received only 47.4 mm of the precipitation.

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TABLE #1. SEASONAL CLIMATIC DATA

MONTH	MEAN TEMP DEGREES C		TOTAL PRECIP mm		TOTAL SUNSHINE HOURS	
	1991/92	LONG TERM	1991/92	LONG TERM	1991/92	LONG TERM
Oct/91	7.7	7.0	13.6	22.0	180.3	172.0
Nov/91	0.2	-0.8	21.0	18.6	138.1	113.2
Dec/91	0.0	-5.8	0.6	18.6	138.8	94.0
Jan/92	0.9	-8.6	2.6	18.7	91.1	98.7
Feb/92	0.1	-6.4	3.8	17.5	168.4	123.9
Mar/92	4.5	-1.7	5.8	24.0	216.6	163.2

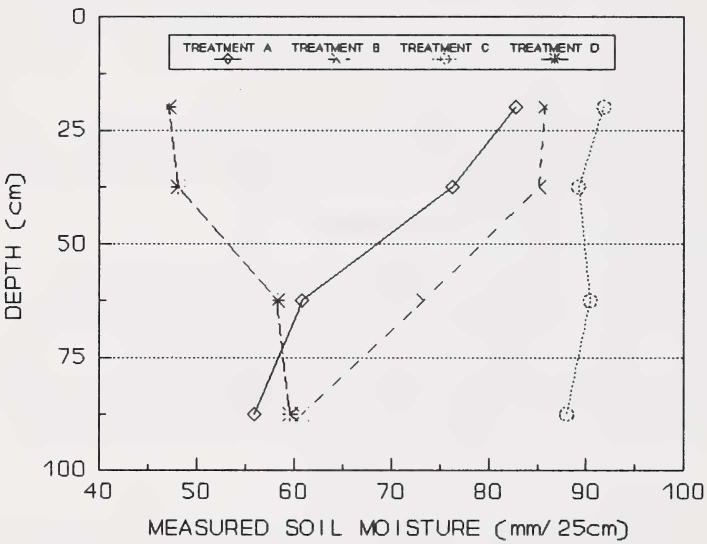

Figure 1. Spring Soil Moisture Levels

In all cases, increasing fall irrigation application amounts brought about higher spring soil moisture levels with depth (Fig. 1). Even with the 47.4 mm of precipitation that fell as over winter precipitation, the non irrigated plots (treatment D) remained below the permanent wilting point in the 0 to 25 cm. range. Table #1 outlines the water holding capacity for the various depths of the root zone.

TABLE #2. SOIL PHYSICAL PROPERTIES - FALL IRRIGATION SITE

DEPTH (cm.)	BULK DENSITY (g/cm^3)	FIELD CAPACITY (mm)	PERMANENT WILTING POINT (mm)	AVAIL. WATER HOLDING CAPACITY (mm)
0-25	1.4	106	49	57
25-50	1.4	112	48	64
50-75	1.4	107	49	58
75-100	1.35	107	47	60
100-125	1.35	103	49	54

In treatments A and B, 91.2% and 91.8% of the applied fall irrigation remained within the 0-100 cm zone at spring seeding. Measured overwinter decreases were 4.8 mm for treatment A and 6.3 mm for treatment B. Treatment C only had only 73.3% of the applied fall irrigation remain on April 1, but exhibited the highest overall soil moisture conditions with depth (Fig. 1). Treatment C had a net loss of 33.3 mm of moisture for the one metre depth. The 125 mm application of water for treatment C resulted in irrigation water penetrating the 50-75 cm depth. This was the only treatment in which this occurred (Figs. 2,3,4&5). During the monitoring period, soil moisture levels of

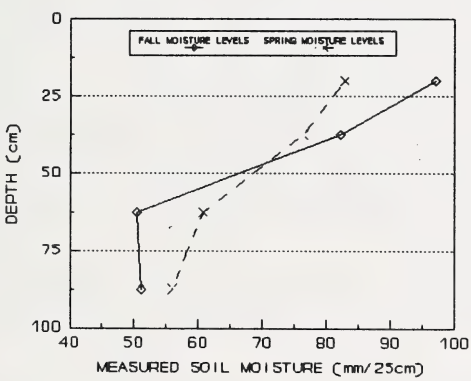

Figure 2. Treatment A

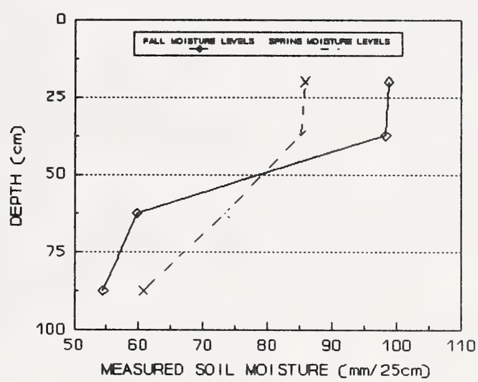

Figure 3. Treatment B

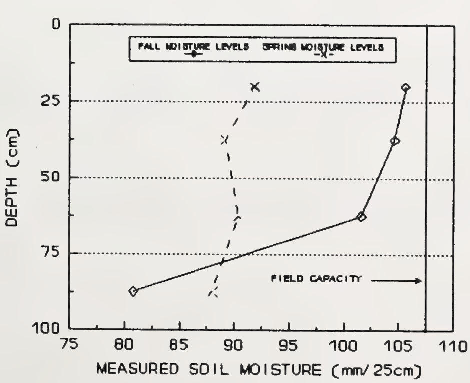

Figure 4. Treatment C

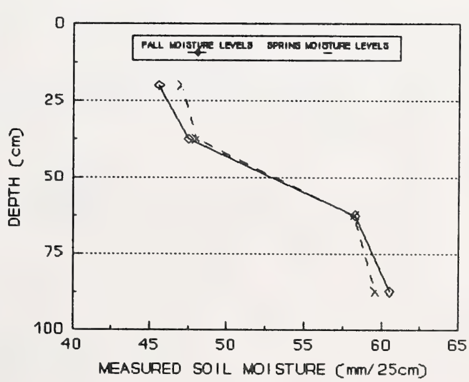

Figure 5. Treatment D

treatment C decreased for the top three soil depth increments and increased for the bottom three increments. There was measured downward movement of soil moisture and as a result moisture was lost below the 0-100 cm zone into the 100-150 cm zone. 15 mm or 12% of the applied irrigation amount was found in the 100-150 cm depth in the spring. Treatments A and B displayed no measurable downward movement of water past the 75-100 cm depth.

Seasonal evaporative losses also increased as fall irrigation amounts increased. Treatments A and B had a total loss of soil moisture of 52.2 mm and 53.7 mm respectively. The total loss of soil moisture includes 47.4 mm of overwinter precipitation. There was a net loss of soil moisture of 8.8% for treatment A and 8.2% for treatment B due to evaporation. Treatment C had a total soil moisture loss of 65.7 mm. With the inclusion of 47.4 mm of overwinter precipitation, this represents 14.7% of the fall application lost due to evaporation.

In looking at the amount of soil moisture lost during this over winter period, the non irrigated treatment lost on an average 0.25mm/day. The fall irrigated treatments lost on an average from 0.28mm/day (treatment A) to 0.44mm/day (treatment C).

SUMMARY AND CONCLUSIONS

This was the first year of the study. Due to the unusually warm and dry winter, this season's data may prove to be a standard by which subsequent years' data are judged.

All fall irrigated treatments displayed fall moisture levels approaching field capacity (107.5 mm/25cm) for varying depths. Treatment A (55 mm application) had only the top 25 cm depth nearing field capacity. Treatment B, which applied 77 mm of irrigation, raised the top half metre to near field capacity. The 125 mm application of treatment C resulted in near field capacity fall moisture levels for the top three 25 cm depths.

All levels of fall irrigation showed soil moisture benefits in the spring. Treatment A increased spring moisture in the top 1/2 metre, treatment B showed gains in the top 3/4 metre, and treatment C raised moisture levels throughout the entire one metre zone. Treatment C, which neared field capacity (107.5 mm/25cm) in the fall for the top three soil depths, was the only treatment to lose water to deep percolation.

The results generated by this initial year of study were from a stubble covered site. Since this is not always the situation for fall irrigated land further years' studies will consider a cultivated site in conjunction with stubble.

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THE INFLUENCE TIMING OF IRRIGATION WATER HAS ON CROP YIELD

R. Riewe, P.Ag., and B. Handerek[1]

INTRODUCTION

The purpose of this report is to look at the effects of timing of irrigation on crop yield. Soft wheat (variety: Fielder) was grown under irrigation using a variety of irrigation schedules (Figure #1). Yield reductions ranged from 12% (498 kg/ha) to 39% (1600 kg/ha), depending on the soil moisture stress maintained by the specific irrigation schedules. Where high soil moisture conditions were maintained, yields ranged from 90% to 103% of Treatment A, the control.

This study was developed to study the effect of various irrigation schedules on crop production. The three main factors on which irrigation farmers base their irrigation scheduling (plant growth, soil moisture, and time of year) were used to create the eight (8) irrigation schedules for this project.

A. 50% of available moisture depleted.
B. 50% of available moisture depleted in the top 50 cm of the root zone only.
C. 50% of available moisture depleted until cut off date of June 30.
D. 1990: 75% of available moisture depleted.
   1991: 50% of available moisture depleted until the flag leaf is visible; 25% of available moisture depleted from flag leaf until harvest.
E. 75% of available moisture depleted until the flag leaf is visible. 50% of available moisture depleted from flag leaf to harvest.
F. 50% of available moisture depleted until the flag leaf is visible. 75% of available moisture depleted from flag leaf to harvest.
G. 25% of available moisture depleted until the flag leaf is visible. 50% of available moisture depleted from flag leaf to harvest.
H. Dryland.

Figure #1. Description of Different Irrigation Schedules

It is to be noted, once these depletion levels are reached, plots are then irrigated back to field capacity.

METHODS

The Project area located in the S.E.1/4 of 2-10-21-W4, approximately 10 km from Lethbridge, was cultivated and seeded by the co-operating owner/farmer. The site was seeded at 123 kg/ha in 1990 and 112 kg/ha in 1991 and 1992. Soft wheat was seeded on May 4 in 1990, April 25 in 1991 and April 23 in 1992. 90 kg of actual N. was applied in each year using a broadcast spreader. Buctril M herbicide was applied according to manufacturer's recommendations the first two years for broad leaf weed control. In 1992, the site was sprayed with Assert for wild oat control followed by a later spraying of Lontrel to control Canada thistle.

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The plots were situated using a randomized block design. Each treatment was replicated 3 times. The size of each plot was 6.1 m x 12.2 m (20′ x 40′) with a 18.3 m (60′) buffer zone between each plot (E-W axis) and a 9.15 m (30′) buffer zone between each row (N-S axis).

Irrigation water application was monitored with a Tru-chek rain gauge located in the center of each plot. During the 1990 season rainfall was measured by means of a rain gauge located just outside the project area and other climatic information (air temperature, solar radiation, and wind travel) was obtained from Agriculture Canada at Lethbridge on a weekly basis. In 1991, an automated weather station was set up at this location. This weather station consisted of a tipping bucket rain gauge, temperature sensor, solar radiation sensor, anemometer, datalogger, and cellular phone. Due to data recording problems with the weather station, Agriculture Canada provided climatic information for the 1992 season.

Soil moisture was determined at 25 cm intervals to a depth of 100 cm with a Troxler Nuclear Moisture Gauge. Immediately after seeding, 1.2 m long aluminum access tubes were installed in the center of each plot. Soil moisture levels were monitored at weekly intervals throughout the growing season. To ensure that all water applied to the soil had infiltrated, soil moisture readings were delayed for a minimum 48 hours after an irrigation or heavy rainfall event.

Yield sampling was performed individually for each plot. This was done by hand harvesting three (3) one-metre square samples, randomly selected from within each plot. In 1992, a single sample was harvested from each plot. The sample consisted of a swath 0.86 m x 10.0 m.

The timing and amount of irrigation water required at each plot site was determined using daily climatic data obtained from the meteorological station located at the site and measured soil moisture levels. Actual crop water use was determined using the modified Jensen-Haise equation.

RESULTS

In all cases, maintaining soil moisture conditions greater than 50% available moisture resulted in higher consumptive values than Treatment A. Treatments D and G had consumptive use values of 8% and 6% greater than Treatment A. No significant increases in yield were attained with the higher water use treatments (97% and 102% for Treatments D and G respectively). The work of Hobbs and Krogman showed that by maintaining soil moisture conditions greater than 50% throughout the crop growing season, crop yields could increase by 5%. Table #1 and Figure #2 give the results obtained over three years for this project.

Table 1: Irrigation water applied, consumptive use and crop yield.

Treatment	Irrigation Water Applied (mm)	Consumptive Use (mm)	Crop Yield (kg/ha)
A	221	348	4136
B	221	345	4284
C	155	327	3639
D*	228	377	4022
E	149	291	2525
F	170	304	3733
G	270	370	4237
H	0	192	1493

* Only two years' data

Maintaining soil moisture conditions at or above the 50% depletion level in the top 50 cm (Treatment B) of the root zone resulted in a yield increase of only 3% as compared to Treatment A. There was a 2% to 11% increase in the amount of irrigation applied to maintain the level of soil moisture above the 50% depletion level in 1990 and 1991. In 1992, the total amount of irrigation water applied on this treatment was 17% less than Treatment A.

The decrease in irrigation water applied was due to the above-average precipitation received in June and July. Soil moisture conditions below the 50 cm level ranged from 20% to 45% of available moisture.

Maintaining soil moisture conditions above the 50% depletion level to the end of June (Treatment C) and then ceasing irrigations thereafter resulted in crop yields being 14% to 18% lower than Treatment A. With above average rainfall received in July of 1992 (180% above the average for the Lethbridge area), Treatment C yielded the same as Treatment A. In 1990 and 1991, cutting off irrigation at the end of June has resulted in yield reductions of 18% and 14% respectively. Table #2 details the precipitation received at the site.

TABLE 2: RAINFALL DATA (MM) FOR LETHBRIDGE AREA, 1990-92

MONTH	1990	1991	1992	AVERAGE
May	45.0	55.0	14.0	53.8
June	21.0	106.8	102.8	72.0
July	47.0	18.0	75.6	41.8
August	0.0	39.0	17.2	42.1

Stressing the crop at any time during its development can reduce crop yields 35% to 40%. Limiting water during the vegetative stage of crop development, as shown with Treatment E, has the greatest impact on yield reductions. Yields were reduced by 39% (1614 kg/ha or 24 bu/acre). Even with the high amount of rainfall received in July, damage caused by moisture stress early in the crop development stage cannot be overcome.

Similarly, when water was limited during the reproductive stage of crop development (Treatment F), yields were reduced by as much as 10% (404 kg/ha or

6 bu/acre). Due to the high amount of rainfall received in July, no reduction in yield was measured. Regardless of when the water was limited, both treatments had similar crop water uses (291 mm Treatment E and 304 mm Treatment F). The amount of water used by the crop was 13-16% less than Treatment A.

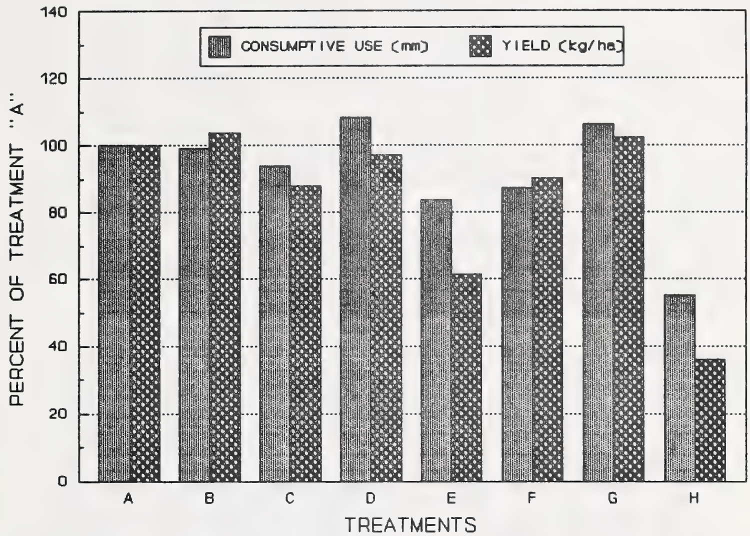

FIGURE #2. YIELD AND CONSUMPTIVE USE DATA FOR SOFT WHITE SPRING WHEAT

SUMMARY AND CONCLUSIONS

In summary, the preliminary findings for the past three years indicate that significant yield losses can and will occur if producers fail to understand the importance of the timing of irrigation on crop production. Irrigation management is an important tool that producers can use to eliminate poor crop yields.

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IRRIGATION MANAGEMENT OF DRY BEANS - 1992

Robert Riewe P.Ag., Vincent Ellert, David Coutts, Bruce Woolhouse[1]

INTRODUCTION

Dry edible beans are an important cash crop in the irrigated region of southern Alberta. There are differing opinions on what type of irrigation schedule will produce maximum yields. Field staff for some of the contracting companies recommend allowing the soil moisture to fall to the wilting point prior to bloom. Other companies recommend maintaining 50% of A.M. (Available Moisture) as a minimum soil moisture level. Alberta Agriculture currently recommends maintaining 40% of A.M. as a minimum level[1]. In order to study the effects of different irrigation schedules on saleable crop yields under field conditions, this study was initiated in 1991.

The objectives of this study were:

1. To evaluate the present irrigation management practices of dry bean production.
2. To develop irrigation management recommendations for dry beans.
3. To update the present irrigation management factsheet for dry beans[1].

METHODOLOGY

Moisture monitoring sites were selected in co-operating farmers' fields. The fields were located in a band along highway #3 from Coaldale east to Medicine Hat. Each site was chosen to be representative of the entire field. A rain gauge used to measure irrigation and a marker flag were installed at each site. Additional rain gauges were located just outside of the irrigated area to measure precipitation. Canola oil was used in these gauges to prevent water evaporation.

Once the crop was planted, soil moisture monitoring was carried out on a weekly basis using the feel method for determining soil moisture[2]. The sample hole was drilled within 4 metres of the marker flag. Samples were taken in 25 cm increments to a depth of one metre. Soil moisture was recorded as a percentage of available moisture. Rainfall, net irrigation amounts, and average soil moisture levels for both the top half metre and the entire one metre root zone were recorded. A copy of this information was placed in a location which was accessible to both the farmer and Irrigation Branch staff. Other data recorded included crop stage, fertilizer applications, chemical applications, stand appearance, and presence of bloom. Data analyses compared the irrigation schedule with the crop yield.

In 1992 a total of 35 sites were monitored. Included in this total are 13 sites in the Lethbridge area which were added to the project in 1992.

RESULTS

A snow storm and freezing temperatures on August 22, 1992 damaged all of the bean crop to varying extents. Only 20 of the 35 sites were harvested. No harvest information is available on bean yields for the Lethbridge-Coaldale-Chin

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[1]Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture and Rural Development, Agriculture Centre, Lethbridge, Alberta T1J 4C7.

areas. Yields of the harvested sites varied from 210 to 1850 net pounds per acre. Average dockage for 1992 varied from 20 to 35%, whereas in 1991, the dockage averaged 7 to 10%. No yield data is presented in this report.

The summer of 1992 was one of the coldest on record. A comparison of corn heat units received during the normal dry bean growing season was carried out for three locations. The results of this comparison are presented in figures 1, 2 and 3. The combination of a cool wet July, early frost and wet harvest period resulted in a very poor year for dry bean production. This study will continue for a minimum of 2 more years.

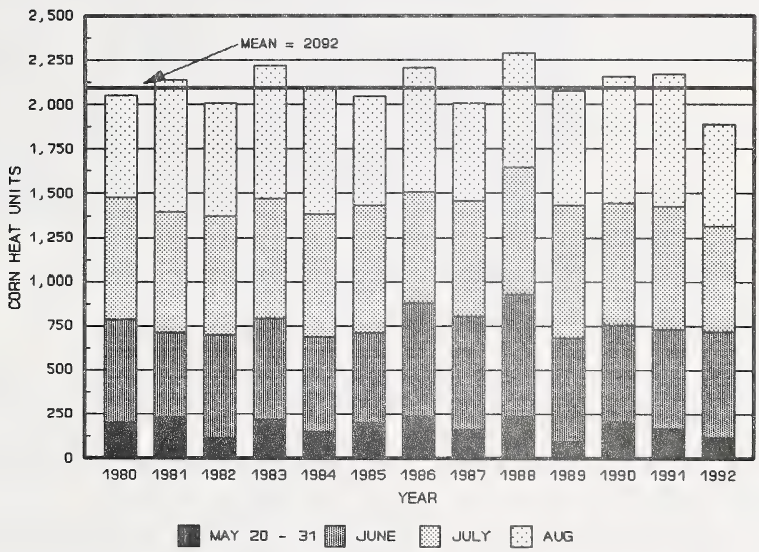

Figure 1 - CORN HEAT UNITS FOR MEDICINE HAT - 1980 TO 1992

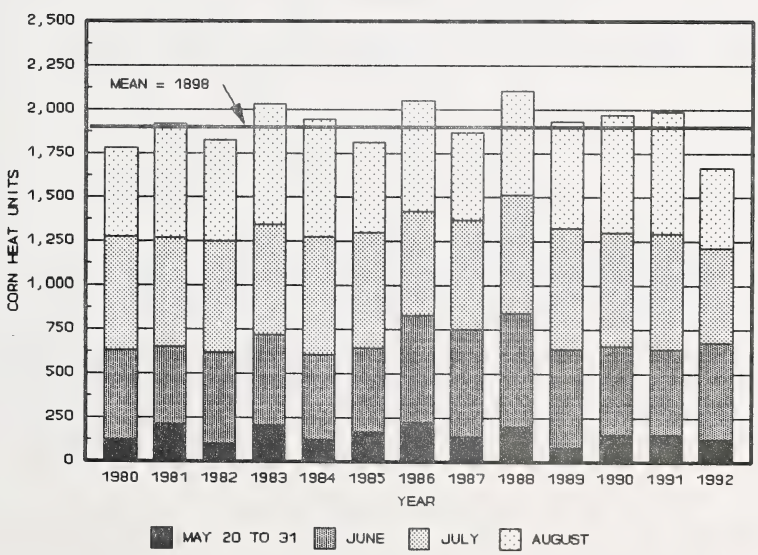

Figure 2 - CORN HEAT UNITS FOR LETHBRIDGE - 1980 TO 1992

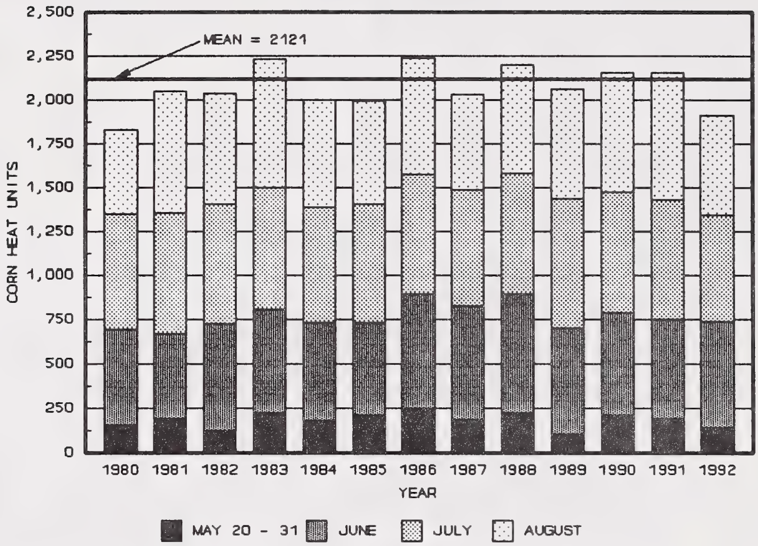

Figure 3 - CORN HEAT UNITS FOR BOW ISLAND - 1980 TO 1992

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EVALUATION OF LOW ANGLE IMPACT SPRINKLERS FOR WHEEL LINE IRRIGATION SYSTEMS

Gord Cook, Larry Kwasny[1]

INTRODUCTION

High winds in Southern Alberta result in high evaporative losses from sprinkler irrigation systems. Much work has been done in the area of center pivot irrigation to limit wind drift, but control of wind drift in wheel line irrigation is more difficult. Because of the fixed spacing and height of wheel line sprinklers, reduction in operating pressure results in poor uniformity. Work was undertaken to determine the feasibility of using lower angle trajectory sprinklers to reduce wind drift and still maintain adequate uniformity.

Objectives

Compare 15 degree trajectory impact sprinklers to standard 23 degree impact sprinklers in varying wind conditions.

Use computer software to simulate uniformity from overlapped sprinkler patterns to determine over all uniformity for standard sets as well as alternate offsets.

Use catch cans to measure uniformity and application efficiency.

METHOD

Two sprinklers were compared. The low angle sprinkler was a Weathertec 15 degree brass impact sprinkler with 7/32 and 1/8 inch nozzles. The standard sprinkler was a Nelson 23 degree brass impact sprinkler with 7/32 and 1/8 inch nozzles. The two sprinklers were located on a common mainline approximately 30 metres apart. This distance prevented their patterns from overlapping each other, but insured similar weather patterns for each sprinkler during the duration of each test. 100 mm diameter catch cans were laid out in 8 radial legs at 2 meter spacings around each sprinkler. (Figure 1) The sprinklers were mounted at a height of 1 meter. A 350 kpa pressure regulator and a water meter were installed below each sprinkler. A pressure gauge was used to check each sprinkler's operating pressure. (Figure 2) Each nozzle flow output was checked volumetrically. This information was compared with the water meter readings to insure accuracy of water volume delivered.

Test duration varied, but volume of water delivered over the test was determined by start and finish readings of the water meters. At the end of the test, the catch can volumes were measured and recorded. Volume caught was compared to volume delivered for an overall percentage caught. Catch can values were entered into a software program called "Catch 3D", created by Utah State University. This software was used to generate coefficients of uniformity (CU) for each sprinkler test as well as 3 dimensional graphical representations of each sprinkler test. The program was also used to simulate overlapped sprinkler patterns for standard sprinkler spacings (12 m X 18 m) as well as alternate offsets. Alternate offsets would occur if the operator offset his lateral spacings by half the standard spacing on each pass over the field.

The sprinkler test site was located at the Ag Canada Substation located 2 km south west of Vauxhall, Alberta. The actual test site was approximately 100

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RADIAL-LEG CAN TEST METHOD

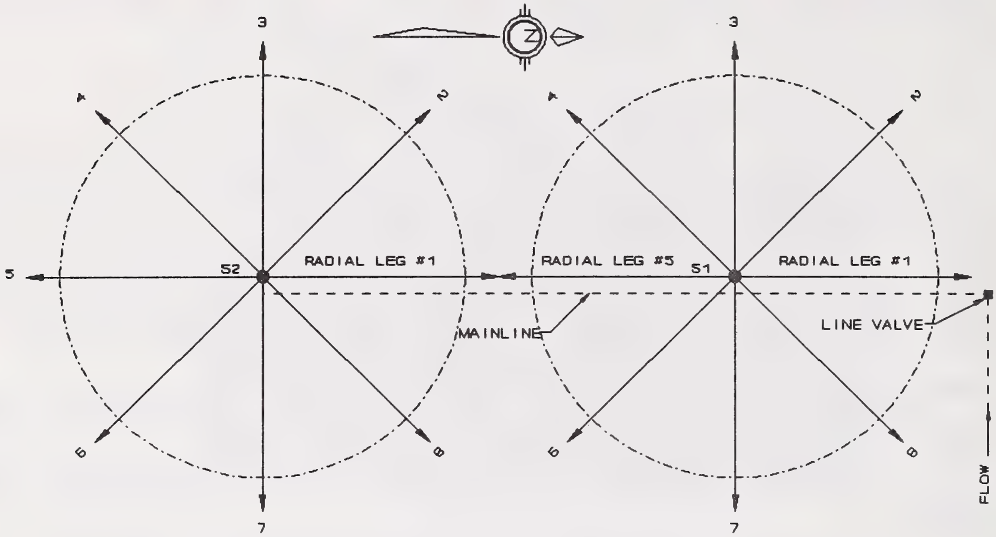


Figure 1

*S1 = 15 deg. LOW ANGLE SPRINKLER, 7/32" x 1/8" NOZZLES
*S2 = 23 deg. STANDARD ANGLE SPRINKLER, 7/32" x 1/8" NOZZLES

- 8 RADIAL-LEGS PER SPRINKLER, EACH LEG = 14m LONG
- CAN SPACING ALONG RADIAL-LEG FROM SPRINKLER = 2m

SPRINKLER LAYOUT

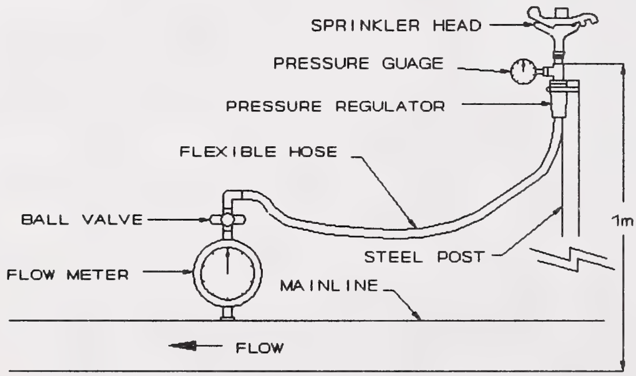


Figure 2

km south west of Vauxhall, Alberta. The actual test site was approximately 100 meters west of a class "A" environment Canada weather station. Weather data

collected for each test included wind speed and direction, relative humidity, and temperature. All tests were carried out according to ASAE testing standard #S330.1, Procedure for Sprinkler Distribution Testing for Research Purposes.

RESULTS

A total of 10 parallel tests were carried out at an operating pressure of 350 kpa. Percent caught, CU for standard spacings and CU for alternate offsets were calculated from each set of catch can data. These results are summarized in Table 1. The average percent caught for the 15 degree sprinkler of 86.2% is 5.3% higher than the average percent caught for the 23 degree sprinkler of 80.9%. CU for standard spacings was 2% higher for the 23 degree sprinkler. CU for alternate offsets was 1.2% higher for the 23 degree sprinkler.

TABLE 1: Catch Can Test Results

DATE	WIND SPEED	15°			23°		
	M/S	CU	CU/ALT	% CATCH	CU	CU/ALT	% CATCH
AUG. 17	2.73	62.8	79.2	73.5	63.9	79.9	65.4
AUG. 18	1.67	86.0	92.8	68.5	89.5	94.6	62.4
AUG. 20	1.46	87.2	93.4	91.4	90.9	95.4	85.3
AUG. 24	2.30	93.6	96.7	102.9	92.9	96.4	94.4
AUG. 26	2.00	69.3	83.3	84.2	70.2	83.8	80.2
AUG. 27	0.89	92.5	96.2	93.1	94.1	97.0	89.3
AUG. 31	2.82	67.4	82.1	88.6	72.7	85.3	83.1
SEP. 01	3.85	63.0	79.4	80.7	65.0	80.6	79.4
SEP. 02	0.30	86.2	92.8	91.8	89.9	94.8	83.4
SEP. 03	0.30	72.6	85.2	87.4	72.0	84.8	85.6
AVERAGE		78.1	88.1	86.2	80.1	89.3	80.9

CONCLUSIONS

The 15 degree sprinklers have a shorter application radius than standard 23 degree sprinklers operating at the same pressure. This shorter radius results in slightly lower CU values for standard spacings as well as for alternate offsets.

The lower sprinkler stream loft exhibited by the 15 degree sprinklers appears to increase application efficiency by 5%.

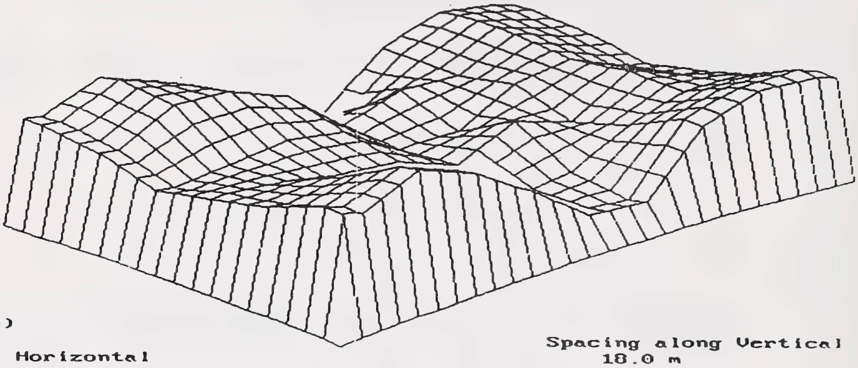
The significantly better CU for alternate offsets for both types of sprinklers suggests that irrigators should be encouraged to use this technique to maximize water application uniformity.

The increase in application efficiency for the lower angle sprinklers warrants further investigation. Irrigators should be encouraged to try these

lower angle sprinklers. These would be recommended only where the irrigator agrees to use alternate offsets, has adequate sprinkler pressure, and has crops and soils which would tolerate slightly lower uniformity in between irrigations.

The following are examples of the Catch 3D Software graphical representation for a 12 m x 18 m sprinkler spacing based on the data collected on August 31, 1992. Results of this test are shown in Table 1.

"23 deg. SPRINKLER 7/32 x 1/8 NOZZLE (51 psi) AUG31S.DAT"

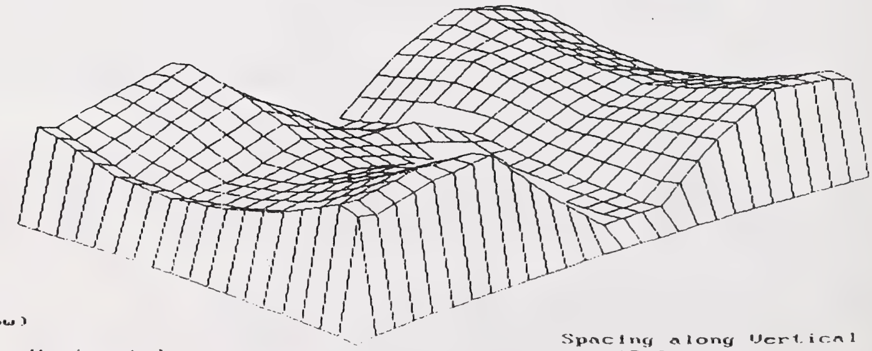


(Top Row)

Spacing along Horizontal
12.0 m
Rectangular Spacing with Sprinkler at Each Corner

Spacing along Vertical
18.0 m
U.C. = 72.7

"15 deg. SPRINKLER 7/32 x 1/8 NOZZLE (51 psi) AUG31N.DAT"



(Top Row)

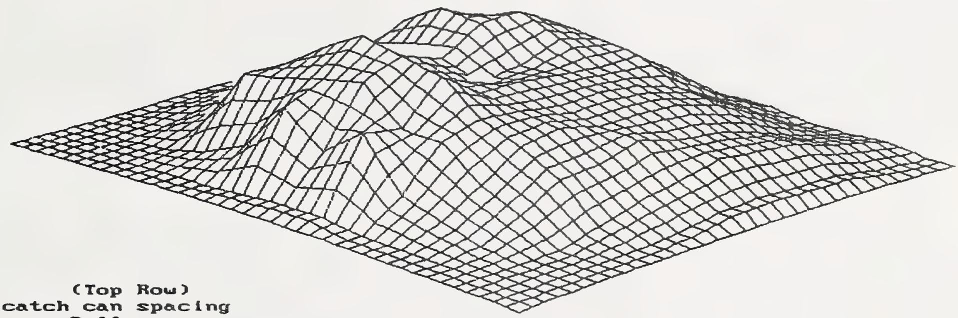
Spacing along Horizontal
12.0 m
Rectangular Spacing with Sprinkler at Each Corner

Spacing along Vertical
18.0 m
U.C. = 67.4

The following are examples of the Catch 3D Software graphical representation for single sprinklers based on the data collected on August 31, 1992.

"23 deg. SPRINKLER 7/32 x 1/8 NOZZLE (51 psi) AUG31S.DAT"

Original Catch Can Data

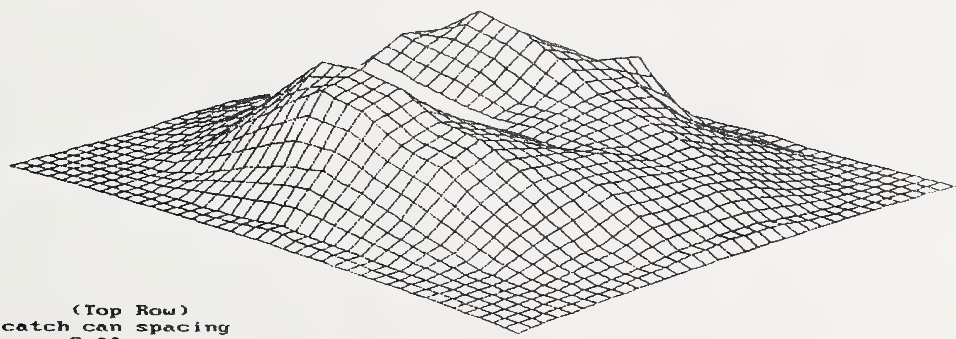


(Top Row)
catch can spacing
2.00 m

Sprinkler is in Center

"15 deg. SPRINKLER 7/32 x 1/8 NOZZLE (51 psi) AUG31N.DAT"

Original Catch Can Data



(Top Row)
catch can spacing
2.00 m

Sprinkler is in Center

DEMONSTRATION OF LOW ENERGY PRECISION APPLICATION EQUIPMENT FOR IRRIGATION AND CHEMIGATION OF POTATOES
FARMING FOR THE FUTURE

ON-FARM DEMONSTRATION PROJECT # 92-F006-1

Marion Rigby, Gord Cook[1]

INTRODUCTION

Objectives

Determine the applicability of modifying irrigation systems to perform the dual function of irrigation and chemical application of insecticides.

Demonstrate irrigation equipment and management practices associated with Low Energy Precision Application (LEPA) technology.

MATERIALS AND METHODS

A three tower, towable pivot located at the Agriculture Canada Research Sub-station in Vauxhall was modified to accommodate three types of low pressure sprinkler heads. Senninger Quad-spray, Nelson Spinner and Senninger Low Drift Nozzles (LDN) were attached to the pivot by drop tubes. Chemigation equipment was installed and included an Agri-inject chemical injection system complete with safety devices to prevent backflow or contamination of chemicals into the water source and a totalizing water meter. A pressure reducing pilot valve was installed to ensure that pivot point pressure remained constant at 105 kpa (15 psi).

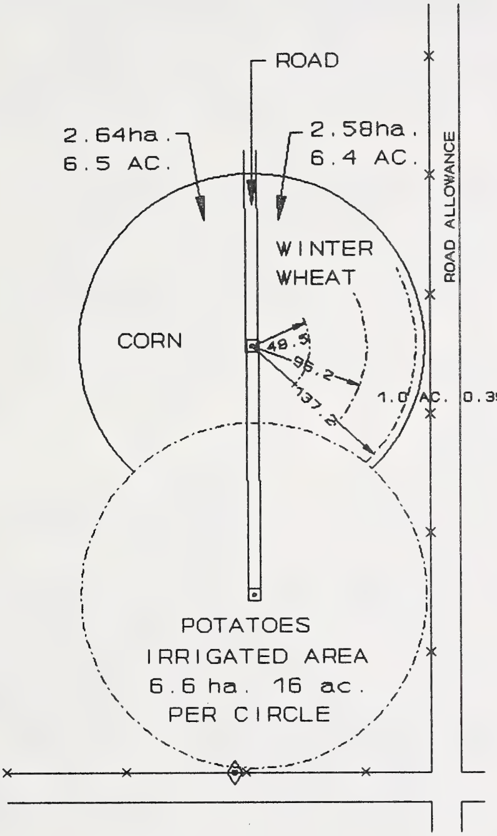
Potatoes were planted in concentric rows under the pivot circle located in the south end of the field while corn was seeded in the west half of the circle located in the north end. The east half of the circle seeded to corn contained winter wheat which was established in the fall of 1991 (Figure 1). A dammer diker was used to form reservoir tillage in the corn plot.

Two rows of neutron probe access tubes were installed in the potato field and one row in the corn. Each row included six access tubes which were equally spaced along a radius from the pivot point. Soil moisture was monitored on a weekly basis and checked periodically by means of the "feel" method.

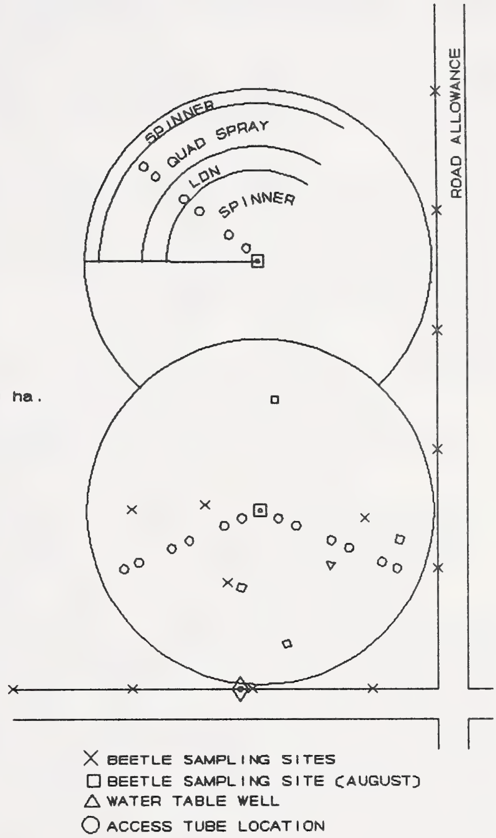
A stainless steel water table well was inserted to a depth of 4 metres in the potato plot. Water table depth was monitored at regular intervals throughout the irrigation season. Water was sampled once pre-chemigation as well as after every chemigation event and again at the end of the season.

Four plots of 30 plants each were isolated for monitoring of Colorado potato beetle. The number of egg clusters, larvae and adults were counted immediately prior to chemigating and 2 days following. Results from chemigated plots were compared with those controlled by conventional ground spraying of potato plots located in an adjacent field.

[1]Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Provincial Building, Taber, Alberta, TOK 2GO.



Crop location and dimension of centre pivot spans.



Location of access tubes, water table well, beetle sampling sites and nozzles.

Figure 1: Schematic of Field Layout.

RESULTS AND DISCUSSION

Chemigation

In all cases, virtually all beetles were eliminated by means of chemical application via the centre pivot with no apparent differences due to nozzle type. Plants were treated twice during the summer, with Ambush (permethrin) on July 22 and Belmark (fenvalerate) on August 15. In August, plots were re-situated in an attempt to locate areas which were more highly infested with potato beetles. Twenty to thirty plants were examined under each type of sprinkler nozzle and a fourth group of thirty plants was treated as a control by spraying with conventional, tractor-mounted equipment. Beetle infestationwas limited to the larval stage in August and there was no evidence of egg clusters prior to chemigation.

Table 1: Chemical Control of Colorado Potato Beetle in August, 1992.

		Pre-Chemical Application		Post-Chemical
Type of Nozzle	Number of plants sampled	Number of plants infected	Total number of bettle larvae	Total number of larvae
Conventional	30	25	121	0
Quad-Spray	20	15	103	0
Spinner	20	19	122	0
LDN	30	15	31	0

Pesticide Leaching and Chemigation Safety

Groundwater samples collected from the water table well were frozen at -40°C. Alberta Agriculture's Land Evaluation and Reclamation Branch has offered to analyze samples this winter to determine if there is any evidence of pesticide leaching. Results from 1992 samples will be carefully examined before continuing with chemigation in 1993.

In general, chemigation provides many safety benefits. For the operator, the chemical application occurs while he is totally removed from the field and the only chemical exposure necessary is for filling of the injector tank. Reduced wind drift resulting from large droplet size and application at low elevation and pressure presents less risk to neighboring crops, animals and humans. Proper management of irrigation amounts and timing should eliminate the possibility of pesticides being leached into groundwater. Eliminating run-off and installing backflow prevention devices safeguards against pollution of surface water sources. Injected chemicals are quickly flushed through the irrigation system to eliminate any residual hazard.

Water Application

Observation of the pivot in operation verified that wind drift was well controlled by positioning nozzles close to the ground. There was virtually no loss due to wind drift once the pivot was in the corn crop.

The water application rate for centre pivots is always highest at the outside edge of the circle. The application rate was 100 mm/hr under the LDN's, 90 mm/hr under the Quad Spray and 50 mm/hr under the Spinner. Application rate can exceed the soil's intake rate. Soils can be ripped and dammer diked to enhance their intake rates and prevent possible run-off. In tests performed on sandy loam soils under our demo pivot, intake rates were increased by as much as 400 % through dammer diking. It is evident that use of the dammer diker with its ripper shanks is effective in dramatically increasing infiltration rates and thereby allowing the use of sprinklers with very high application rates. More work needs to be done to determine whether or not the reservoirs are as necessary as the ripping shanks for maintaining high infiltration rates. Elimination of the reservoirs could promote more widespread acceptance of ripping to prevent run-off.

Row crops were planted in concentric rows to further reduce run-off potential. Concentric seeding requires some planning prior to planting to accommodate row spacing and span length but is easy to implement in the field. To ensure accuracy, each pivot span should be seeded as a separate field,

using the pivot wheel tracks as the starting mark. If possible, each span should be seeded starting from the inside and outside wheel track and meeting in the centre of the span. This reduces the number of "guess" rows and leads to higher seeding accuracy. Circular seeding allowed for easy passage of the furrow drop tubes, even after the corn was damaged by a heavy snow storm.

Energy Consumption

Nozzles used in this demonstration required modification of the centre pivot to reduce the pressure from 480 kPa (70 psi) at the pivot point to 103 kPa (15 psi). It was calculated that converting the centre pivot from a regular, high pressure, impact sprinkler system to Low Energy Precision Application resulted in an 80% reduction in energy consumption. This 80% reduction is comprised of the reduction in pressure required and the increase in application efficiency. Based on 1992 TransAlta price of $.06 per kw hr for electricity, the energy bill for this particular system would have decreased from $18.40 per net acre-ft to $3.33 per net acre-ft of water applied.

CONCLUSIONS

Preliminary results indicate that injecting chemicals through a Low Energy Precision Application centre pivot system is a viable means of controlling Colorado potato beetle. The benefits of chemigation include reduced human exposure, decreased machine traffic, more flexibility in application timing related to weather conditions, reduced application cost, and reduced risk from drift - especially when compared to aerial application. The injection system used in this demonstration proved easy to calibrate and effective in mixing and pumping chemicals into the pivot lateral.

All nozzles exhibited adequate wetting patterns and drop tubes were proficient at controlling wind drift. Reservoir tillage prevented the occurrence of soil erosion by water, even under the extremely high application rates experienced when Quad-spray nozzles were put into bubble mode. Planting corn in a circle allowed drop tubes to fall between rows so that there was no damage which would have occurred had irrigation equipment snagged on the crop.

Concentric seeding ensured that the pivot was always discharging water into all rows simultaneously. Conventional, linear seeding allows centre pivots to discharge water into only a few rows at a time when positioned parallel to the rows. Concentric seeding reduces run-off potential, especially under low pressure applications.

Energy and water savings are significant enough to warrant investment in low pressure sprinkler packages for centre pivots. The capital cost and energy savings are dependent on present system configuration and operating pressures. The feasibility of low pressure conversion is totally dependent on run-off potential which is a function of topography, soil type, and cropping practices.

The dammer diker was extremely effective in increasing infiltration rates. More work needs to be done to quantify the actual benefits and minimize the roughness associated with the formation of reservoirs at the soil surface.

Use of LEPA heads in the furrow bubbler mode is impractical based on current energy and water costs in Southern Alberta. Run-off problems outweigh the benefit derived from totally eliminating wind drift and reducing surface evaporation by wetting only half of the soil surface. Use of the bubbler mode necessitates a drop in every other furrow, which increases capital cost.

Applying water at low elevation, out of the wind, while maximizing

application radius provides the most benefit while minimizing additional management and capital expenditures. Sprinkler heads need not be in every other furrow if placed slightly above the crop canopy as was done for potatoes. In the corn crop, the sprinklers were able to penetrate across rows at the base of the corn stalks, and provided adequate coverage even when two or more rows of corn were between sprinklers.

Feedback during demonstrations for tour groups was extremely positive with much interest expressed in the energy saving aspects of low pressure irrigation systems as well as the dual function of insect control with the addition of a chemical injector. The demonstration site was toured by 120 people in 1992.

VARIATIONS IN SPRING-TIME EROSION MEASURED WITH A RAINFALL SIMULATOR

S.C. Nolan, T.W. Goddard and K. Skarberg[1]

ABSTRACT

Field measurements of soil erosion by water are needed to quantify seasonal variations in erosion in Western Canada. A field study was conducted to measure soil erosion in undisturbed conditions on a summerfallowed Dark Gray Luvisol, using a portable rainfall simulator. The simulations were conducted during 1991 and 1992 at an intensity of 60 mm/h for 20 minutes. The spring conditions evaluated were: i) partial thaw to 5 cm ii) partial thaw to 20 cm, and iii) complete thaw. Elapsed time to start of runoff, and time to initial soil loss, total accumulated runoff and total accumulated soil loss were measured during each rainfall simulation. Treatments were characterized on the basis of bulk density, soil moisture, and soil surface roughness. The results showed that the partially thawed soils were significantly more susceptible (14 to 21 times) to water erosion than were fully thawed soils. Amounts of runoff and soil loss were significantly positively correlated with antecedent soil moisture.

INTRODUCTION

Seasonal variations in soil erosion need to be quantitatively evaluated and characterized to effectively implement erosion control measures in Western Canada. Chanaysk and Woytowich (1987) indicate that soils in the Peace River region are particularly vulnerable to erosion in spring conditions when infiltration is impeded. Another study in the Peace River region revealed that as much as 80 per cent of the annual runoff occurred in spring conditions, causing 50 per cent of the annual soil erosion (van Vliet et al., 1984). Other soil loss data from continuous fallow plots also indicate that soil erodibility is not constant throughout the year (Mutchler and Carter, 1983).

In a laboratory study in Ontario, Wall et al. (1988) found that the greatest amounts of soil erosion occurred during the winter-spring thaw conditions. A study of erosion under simulated rainfall at different thaw depths (Benoit et al., 1990) indicated that the greatest impact on runoff was caused by bulk density followed by soil moisture content. The greatest impact on soil loss was caused by total water runoff, followed by aggregate stability, roughness and thaw depth. The factor with the least impact on soil loss was soil moisture, followed by bulk density.

The objectives of this study were to measure and characterize variations in runoff and soil loss in undisturbed springtime field conditions representative of partially and fully thawed soils. A summary of the interim results of this study is reported elsewhere (Nolan and Goddard, 1992b). A comparison of erosion during spring conditions with erosion during summer conditions has also been made (Nolan and Goddard, 1992c; Skarberg, 1993).

The results of various other studies of soil erosion by rainfall simulation have also been reported (Nolan and Goddard, 1992a).

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[1] Research Agronomist, Soil Conservation Specialist and Assistant Research Agronomist, respectively, Conservation and Development Branch, Alberta Agriculture, Edmonton.

METHODS

Difficulties with studying erosion in field conditions include the unpredictable nature of rainstorms and the difficulty characterizing and repeating them. The Guelph Rainfall Simulator (GRS II) was developed for use as a field tool to obtain site specific, repeatable measurements of soil erosion in field conditions (Tossell et al., 1987). A modified version of the GRS II simulator was used to initiate erosion from a 1 m^2 plot in undisturbed field conditions. Specifics of the simulator and study set up are described in Nolan and Goddard (1992c).

Total runoff (water and soil) which moved off of the plot during the simulation was collected into sample bottles by suction. Total runoff amounts were determined gravimetrically and then converted to a volume measurement (assuming a 1:1 correlation as sediment concentrations were low). Total amounts of sediment in the runoff (soil loss) were determined gravimetrically after oven drying. Elapsed time to runoff start was recorded to indicate the time at which infiltration rates decreased due to plot saturation. Elapsed time to initial soil loss represents the point at which soil loss was first collected from the end of the runoff collection trough (not always the same as time to runoff start).

Study sites were located on slopes of 5 percent on a loamy, Orthic Dark Gray Luvisol near North Cooking Lake, Alberta. The site was summerfallowed for two years and as such had little residue cover. Treatments were characterized on the basis of surface characteristics (0-6 cm) using gravimetric soil moisture, bulk density (core method), and a measurement of surface roughness (Romkens and Wang, 1986).

The simulations were conducted during 1991 and 1992 at an intensity of 60 mm/h. Three spring conditions were evaluated: i) partial thaw to 5 cm, ii) partial thaw to 18 cm and iii) complete thaw. All simulations were conducted for, or extrapolated to, 18 minute end times. The characterization and rainfall simulation measurements were repeated two to three times for each treatment over a 1 to 2 day period.

Differences between measurements from each treatment were tested for statistical significance using the ANOVA procedure of SAS (SAS Institute Inc., 1987), with a significance level of $P = 0.10$. Means were separated using the Student-Newman-Keuls test. The Pearson Product moment was used for correlational analyses.

RESULTS AND DISCUSSION

Treatment characteristics of the study site during 1991 and 1992 are presented in Table 1. For both years, soil moisture levels in the partially thawed spring conditions were significantly ($P=0.10$) higher than in the fully thawed condition. There were no significant differences in surface roughness or bulk density values between any of the treatments (the latter values ranged from 1.0 to 1.4 Mg m^{-3}).

Table 1. Selected treatment characteristics during spring conditions. Target rainfall intensity of 60 mm/h.

TREATMENT	Soil Moisture (%)	Surface Roughness Index	Time to Runoff Start (min)	Time to Initial Soil Loss (min)	Total Runoff (L/18 min)	Total Soil Loss (g/18 min)
a) 1991:						
5 cm Thaw	44.1 a	146 a	0.5 b	0.5 b	15.0 a	18.8 c
20 cm Thaw	26.0 c	152 a	1.0 b	3.0 a,b	8.4 b	45.6 b,c
Complete Thaw	13.9 d	95 a	3.2 a	5.0 a	0.4 c	3.7 d
b) 1992:						
5 cm Thaw	46.4 a	102 a	0.6 b	0.6 b	15.0 a	165.0 a
20 cm Thaw	36.0 b	105 a	0.9 b	0.9 b	14.6 a	95.7 b
Complete Thaw	15.8 d	121 a	1.1 b	4.0 a	1.2 c	7.0 c

Values in a single column followed by the same letter are not significantly different at P=0.1.

Runoff:

Values of the erosion parameters measured are presented in Table 1. For both years, elapsed time to runoff start lengthened as thaw depth increased, indicating that infiltration into the plots increased as thaw depth increased. Total accumulated runoff was significantly different between all treatments. In 1992, there was no significant difference in runoff amounts from the 5 and 20 cm thaw treatments, but total runoff from both of the partially thawed treatments was significantly greater (12 times) than from the completely thawed treatment.

Correlational analyses revealed that runoff start times were negatively correlated with soil moisture amounts ($r = -0.66$, $P = 0.0051$) and with total runoff ($r = -0.63$, $P = 0.0079$), indicating that as soil moisture increased, runoff start times shortened, and as runoff start times shortened, total runoff increased. Total accumulated runoff was very highly positively correlated with percent soil moisture ($r = 0.92$, $P = 0.0001$) indicating that as soil moisture increased, runoff increased.

Soil Loss:

Time to initial soil loss lengthened as thaw depth increased in both 1991 and 1992. As well, the difference between time to runoff start and time to soil loss start lengthened with increasing thaw depth, indicating that soil erosion occurred increasingly later after initial runoff start times. In 1991, total soil loss was 13 times greater from the 20 cm thaw treatment than from the completely thawed treatment, however there was no significant difference between all treatments. In 1992, total soil loss was greatest from the 5 cm thaw treatment; significantly greater (24 times) than from the completely thawed treatment. Soil loss from the 20 cm treatment was also significantly greater (14 times) than from the completely thawed treatment.

Correlational analyses revealed that time to initial soil loss was negatively correlated with both total runoff and total soil loss ($r = -0.86$ and -0.60, respectively). Total soil loss was significantly positively correlated with soil moisture ($r = 0.72$, $P = 0.0014$) and with total runoff ($r = 0.73$, $P = 0.0013$).

These results suggest that frozen soil layers appear to impede infiltration into partially thawed soils, resulting in higher soil moisture, leading to shorter runoff start times, greater amounts of runoff, and generally greater soil

loss. The frozen layers may also act to reduce amounts of soil available for transport, such as in the 1991 5 cm thaw treatment, although this was not apparent in 1992. An unmeasured factor which may have also contributed to the variability of results was differences in the depth to the frozen soil. Probing the soil with a thin wire illustrated that the frozen layer was wavy and pitted even within the runoff plot.

The erosion data collected in 1991 and 1992 were pooled to identify trends over the two year study period. Figure 1 presents the two year average values of total accumulated runoff and soil loss from the treatments measured. There were no significant differences between runoff and soil loss from the partially thawed treatments, but both were significantly greater than from the completely thawed treatment. Relative to the completely thawed treatment, average runoff was 21 and 16 times greater from the 5 and 20 cm thaw treatments (respectively) and soil loss was 18 and 14 times greater from the 5 and 20 cm thawed treatments (respectively).

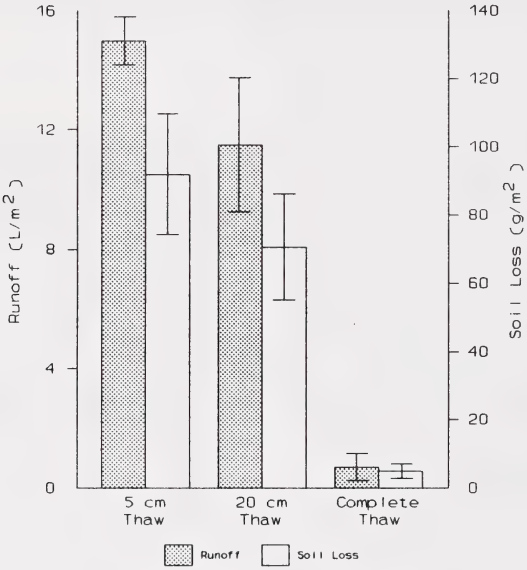

Figure 1:Two year average of runoff and soil loss from a summerfallowed Dark Gray Luvisol

SUMMARY AND CONCLUSIONS

Amounts of runoff and soil loss were measured in the field during spring conditions of partial and complete thaw on an undisturbed Dark Gray Luvisol loam soil using a portable rainfall simulator. Differences in runoff start times and amounts of runoff and soil loss from the various treatments were measured. Partially thawed soils were significantly (14 to 21 times) more susceptible to water erosion by rainfall than were fully thawed soils. Soil loss was significantly related to thaw conditions (where infiltration is impeded and soil moisture is high). Total accumulated runoff and soil loss were significantly negatively correlated with soil moisture. These results indicate that the potential for runoff and soil loss is drastically increased during the spring thaw period. Field management to prevent erosion must take into consideration the vulnerable spring thaw conditions.

ACKNOWLEDGEMENTS

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THE EFFECTS OF A VEGETATIVE CONTROL ON THE RECLAMATION OF A SALT-AFFECTED SOIL

D. Wentz and B. Read[1]

INTRODUCTION

The presence of shallow groundwater and its transport of soluble salts by capillary action into surface soils is the primary cause of dryland salinity. Some methods of removing groundwater such as subsurface drainage schemes can be costly and are often largely ineffective. The lowering of water tables by vegetative consumptive use is a more commonly recommended and successful practice. Deep-rooted forages, such as alfalfa have the ability to extract large volumes of water from considerable depths and are, therefore, ideally suited for groundwater management and ultimately the vegetative control of dryland salinity. At a site in the Crossfield, Alberta area, a project was conducted to study the effect which vegetative controls have on the reclamation of a salt-affected soil.

METHODS

Site Description:

The saline seep studied is found in a closed basin, located in the southeast quarter of section 26-28-28 W4, about 15 km east of the town of Crossfield. The seep itself is side-hill in nature and is associated with an upslope bedrock ridge. The dominant soils in the study area are Orthic Black Chernozemic of loamy texture. The parent material is a glacial till of ground moraine origin and is on average < 3m in thickness. The underlying bedrock is an interbedded sandstone of the non-marine Paskapoo formation. The topography is a very gentle (2-5 %) slope.

Instrumentation:

In the spring of 1990, the study area was instrumented at four positions on the slope (1831 - 1834) (Figure 1). A total of eleven piezometers and four observation wells were installed at depths ranging from 2.1 to 19.1 m. Continuous water table recorders charted groundwater movement at sites 1831, 1832 and 1834. Meteorological equipment is also present on site.

Data collection:

Groundwater from all wells and piezometers was sampled on a routine basis year round. Soil sampling to 3 m has also been performed on a regular basis since the outset of the study. Both groundwater and soil was analyzed for EC, pH, SAR, cations and anions. Soil moisture content is monitored at depth throughout the growing season. Rainfall was measured in gauges located at sites 1831 and 1834. In 1991 an automated climate station was set up to monitor a number of meteorological parameters.

Cropping:

In 1990 the entire study area was seeded to wheat. A 50 m strip of barley was reseeded in mid June along the east field boundary due to poor emergence of

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the wheat in that area. In 1991, the upper field was put into wheat again, with the lower field in an alfalfa-wheat grass mix as a salinity control measure. In 1992, peas were seeded upslope with the forage mix remaining in the lower slope position.

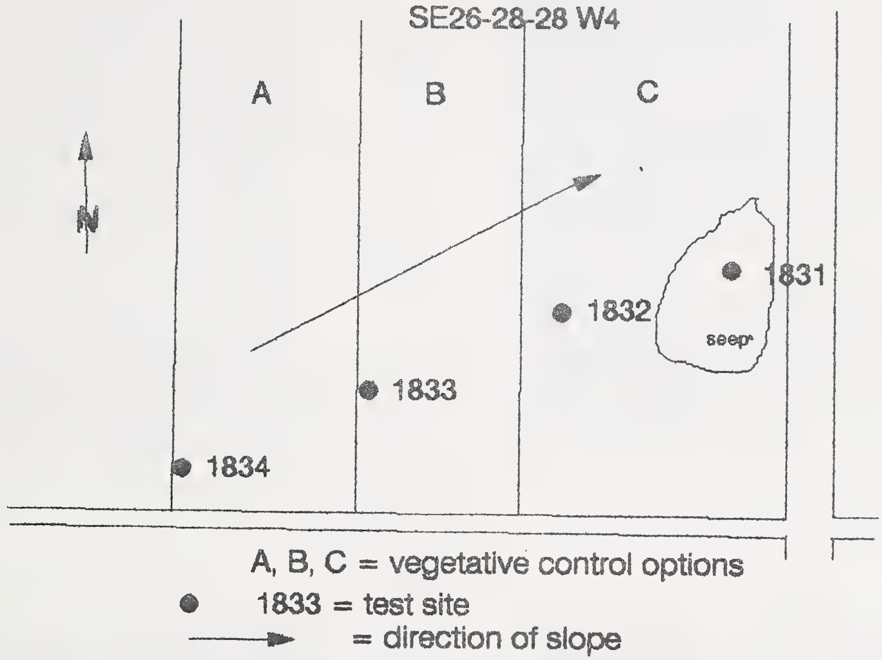


Figure 1. Study area showing test sites and location of vegetative control options (nts).

RESULTS

Soil salinization in the lowerslope position (sites 1831 and 1832) can be attributed primarily to shallow groundwater discharge. Some surface water discharge occurs after major rainfall or runoff events and this contributes to a lesser extent to the shallow groundwater situation. Most of the groundwater recharge occurs upslope (sites 1833 and 1834) in a number of depressions. The water enters the system here and is transmitted laterally through coarse textured layers in the till, becoming increasingly saline as it approaches the lower slope position. The groundwater discharges downslope where the sand and gravel layers subcrop at a shallow depth.

Three main vegetative recommendations were put forth to control and manage the groundwater. Each recommendation was based on the slope position of the control, either (a) upper (b) mid or (c) lower (Figure 1). The control implemented in this case involved seeding approximately eight hectares of

alfalfa/grass mix in the lower slope position.

Groundwater Movement:

Groundwater movement at sites in the recharge area (1833 and 1834) showed only minor seasonal fluctuations, with mean groundwater depth generally constant throughout the study period (Figure 2). Groundwater movement in the discharge area was very different. In well 1831, groundwater become most shallow in 1990 and 1991 at a depth of about 0.3 m. In 1992, one year after the planting of alfalfa, the peak shallow depth only reached 0.7 m, over twice as deep as in the either of the previous two years. Similarity, at well 1832, the groundwater in 1990 and 1991 came within 0.8 m and 0.7 m of the soil surface (respectively). In 1992, the groundwater only reached a peak shallow depth of 1.6 m, or twice as deep. This reduction in groundwater depth occurred in spite of the fact that 1992 received 75 mm of rainfall more than that recorded in 1991, and an amount equal to that which fell in 1990. Alfalfa has the ability to root to a depth of 1.8 m in its first year of growth. Extraction of water by the crop in this instance is demonstrated in these deeper groundwater depths.

Groundwater Quality:

Regression analysis was used to show trends in groundwater salt content over time. Plotted linear functions, using groundwater quality data from discharge site wells 1831 and 1832 indicate a declining trend in groundwater EC (Figure 3). Actual groundwater EC in well 1831 ranged from a high of 15.6 dS/m in July of 1990 to a low of 3.6 ds/m in January of 1992. In well 1832, the highest EC value occurred in October of 1990 with a low value of 2.0 recorded in October of 1992. In both cases, the lowest EC's occurred one year after the implementation of the alfalfa.

Soil Quality:

At site 1832, mean soil EC (0-120 cm) remained relatively stable throughout the study period, showing seasonal fluctuations and only a slight trend towards improved soil quality (Figure 4). Mean EC's ranged from a high of 10.8 dS/m in January, 1991 to 5.6 dS/m in February, 1992. In the region of site 1831, the presence of shallow, saline groundwater aggravated the soil salinity situation. Seasonal cycles of leaching and evapotranspiration also resulted in wide fluctuations in the soil salt status at this site. Despite this, a significant trend toward lower soil EC was apparent. Means EC's in the region of site 1831 were highest in mid 1990, with the lowest level recorded in April of 1992. As with the groundwater quality, soil quality was the best (lowest EC) in the year following the planting of alfalfa. The deeper water tables which occurred in the latter stages of the study period may be providing the opportunity for some leaching to be taking place.

CONCLUSION

After only one year of vegetative control, trends toward lower water table, improved soil and groundwater quality and overall salinity reclamation are evident. The placement of alfalfa in the lower slope position will continue to drive the reclamation process as the alfalfa roots deeper and continues to draw down the water table. The expansion of the alfalfa acreage upslope is planned for 1993. This measure should intercept a larger volume of groundwater moving downslope and cause a more rapid reduction of the water table and lower salinity levels at the seep. Monitoring of the parameters influencing soil salinity will continue at the site.

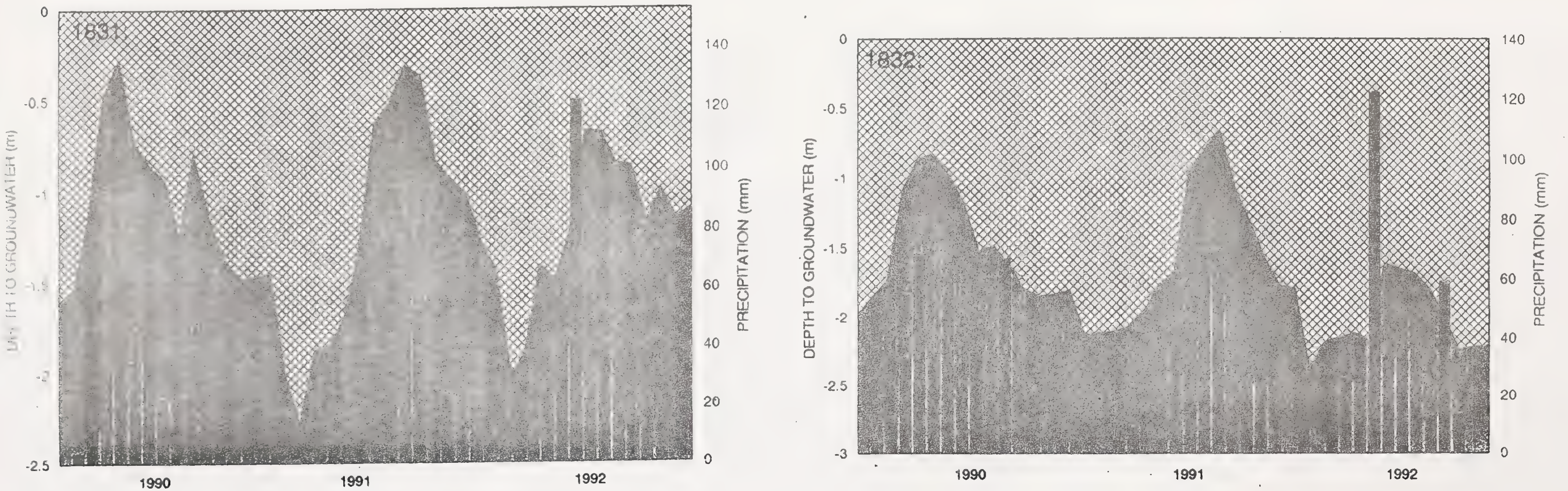
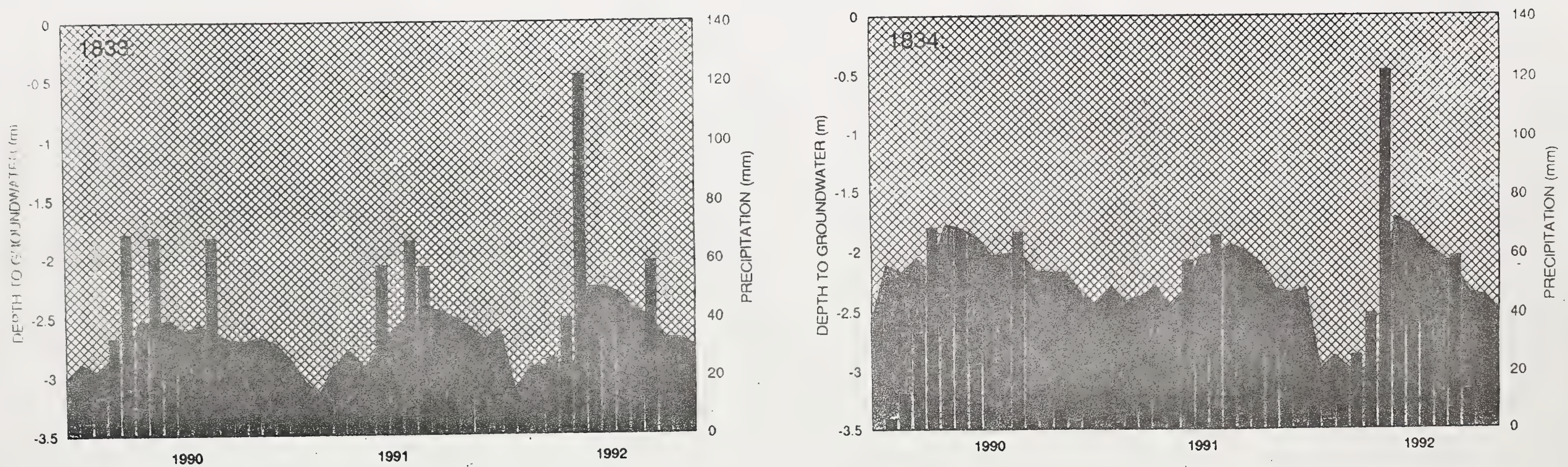
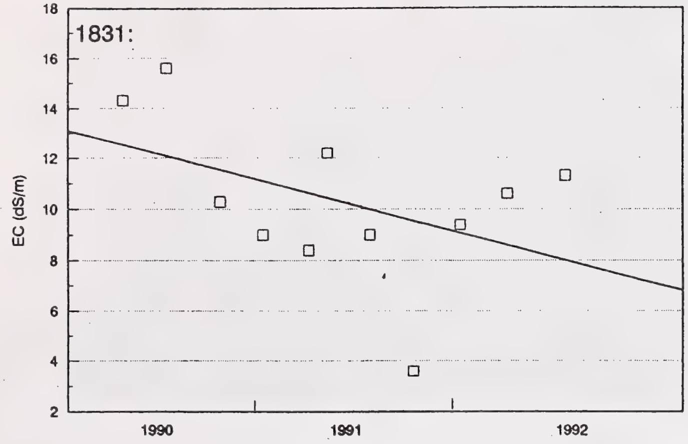


Figure 2. Groundwater movement at the four data collection sites over the course of the study period, including precipitation





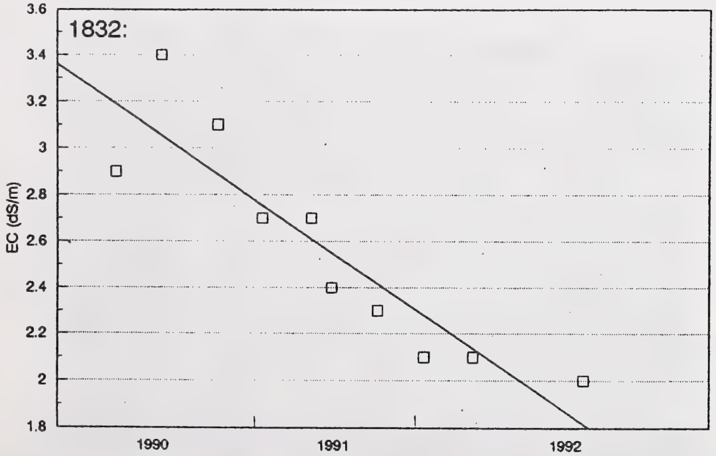
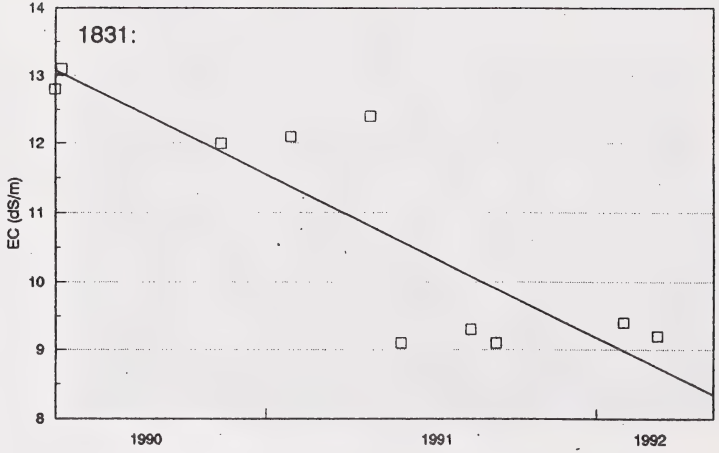


Figure 3. Groundwater quality at discharge sites



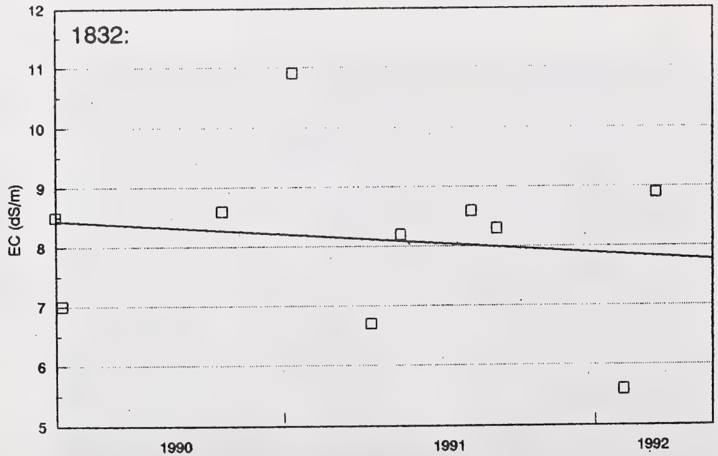


Figure 4. Soil quality at discharge sites

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DEVELOPMENT OF A SOIL SALINITY EXPERT SOFTWARE SYSTEM

Don Wentz, Curt Livergood and Bill Read[1]

INTRODUCTION

Soil salinity is a major agronomic problem affecting both irrigated and dryland in semi-arid regions of the North American Great Plains (Doering and Sandoval 1981). Soils affected by salinity are estimated to be 2.2 million hectares (5.5 million acres) across Alberta, Saskatchewan, Manitoba, Montana and North Dakota (Brown 1983). Three percent of Alberta's agricultural land base (647,000 hectares [1.6 million acres]) is affected (Vander Pluym 1992).

Control and reclamation of dryland salinity requires an understanding of the dynamics of groundwater and salt flow patterns in the soil. A hydro-geological investigation can confirm these interactions but in routine situations a recommendation can be made without an investigation if the proper criteria is followed.

With this in mind, the Conservation and Development Branch of Alberta Agriculture undertook the development of A Soil Salinity Expert Software System (ASSESS). The ASSESS program is a computerized program which enables a knowledgeable investigator to assess and formulate a specific control and reclamation program for a salinity problem.

OBJECTIVES

The primary objective of a dryland salinity investigation is to determine practical management alternatives for controlling soil salinity (Vander Pluym, 1992). With increased requests for salinity investigations, the role of the salinity specialist will be altered to one of consultation rather than investigation. Thus, the Conservation and Development Branch of Alberta Agriculture is modifying the salinity investigation process to assist in the transfer of this technology.

The intent of the ASSESS program is to develop a system whereby a producer can have direct input into the control and reclamation of a saline affected area. A data base developed by the Conservation and Development Branch will assist in the investigation.

MATERIAL AND METHODS

The ASSESS program requires a personal or lap-top computer, a printer and supporting software. The ASSESS program follows a question and answer driven computer program designed to derive a set of recommendations based on previous investigations and experience.

Where **HIGHLIGHTED**, the ASSESS program gives more information by pushing the F1 key. This is a help key which identifies and explains all the parameters associated with the conditions identified by the landowner and the investigator.

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A SOIL SALINITY EXPERT SOFTWARE SYSTEM (ASSESS)

ASSESS is a question and answer driven computer program, designed to develop a set of recommendations which can be implemented to control the spread of soil salinity and reclaim salt-effected land.

FARMERS NAME: ____________________

LEGAL DESCRIPTION: ________________

COUNTY: _________________________

INVESTIGATOR: ____________________

DATE: ___________________________

When **HIGHLIGHTED** additional information is available in more detailed format by pushing the F1 key.

1. What is the dominant texture of the soil in the area, not visibly saline?

   COARSE MEDIUM FINE

2. Are there any other saline areas on your land or an immediately adjacent land?

   YES NO

3. Is the RECHARGE area on your land?

   YES NO

4. Are any of the following factors present which may indicate a salinity problem?

Is PRODUCTIVITY AFFECTED?	YES	NO
Are SALTS visible on soil surface?	YES	NO
VEGETATION INDICATIVE of salinity?	YES	NO

   If YES to any 1 condition PROCEED. If 3 NO's - TERMINATE

5. How many acres does the affected area comprise?
   ACRES x FACTOR = TOTAL AFFECTED AREA

   0 to 1 x 10 =
   1 to 2 x 7 =
   > 3 x 5 =

6. What is the dominant type of VEGETATION currently growing in the saline area?

   __________ = LOW SALINITY
   __________ = MODERATE SALINITY
   __________ = HIGH SALINITY

7. Which position on the slope is salinity located?

CREST, UPPER, MIDDLE, LOWER

TOE, DEPRESSION

7a. Does water pond in affected area after rainfall or snowmelt?

NO

YES

7b. Does affected area remain wet long after a rainfall or snow melt event when other areas have dried?

YES

NO

GROUNDWATER CONTRIBUTION
SEEP

SURFACE WATER CONTRIBUTION
SEEP

8. Do you have obvious SPRINGS or SOAP-HOLES?

NO

YES

a. Free Flow Groundwater

TEXTURE CHANGE
SLOPE CHANGE
GEOLOGIC OUTCROP

b. Pressurized Seep

HYDRAULIC DISCHARGE

c. Surface Water Seep

BATHTUB RING
DEPRESSION BOTTOM

RECOMMENDATIONS:

If answer to 8 NO = a, then Recommendation # 1

1) Seed the visibly Affected area x 1.5 to:
(factor)

SALT TOLERANT GRASS at a rate of _______?

Seed the area immediately upslope and perpendicular (visibly affected area x 5) to ALFALFA at a RATE OF _______?

Seed the remaining upslope area to CONTINUOUS CROP or FLEX CROP

If 8 YES = b then Recommendation # 2

2) Seed the visibly affected area x 1.5 to:

SALT TOLERANT GRASS at a rate of ________?
at a rate of ________?

Seed the remaining upslope area to CONTINUOUS CROP

2a) Do you wish to implement MECHANICAL MEANS to control groundwater?

If Recommendation 2a = YES then Further Investigation
If Recommendation 2a = No then Terminate

YES → Recommend further investigation into:

RELIEF WELLS
INTERCEPTOR LINES

NO → Terminate

If 7b = NO then 8c = Recommendation # 3

3) Channel Surface Water through a GRASS WATERWAY into a Natural drain of CONSTRUCTED DRAIN.

Seed an ALFALFA GRASS MIXTURE into parameter of Salt Affected Area x 1.5

DISCUSSION

In order for the ASSESS program to assess the type and severity of the salt affected area and to make a reasonable recommendation, several factors have to be considered. First, the landowner's knowledge of the land is essential. Second, the investigator's knowledge of the immediate area, plus some soils and groundwater experience, is required. Third, the questions and answers must be followed in an orderly fashion in order to arrive at a reasonable and accurate conclusion. In order to develop accurate conclusions, all of the variables must be identified.

CONCLUSION

The ASSESS program is designed to allow the knowledgable individual to identify the causes of a salinity problem and derive logical and cost effective recommendations for reclamation and control. Presently, the program is in the development stage and will require further testing in both the office and field stage. Ultimately, it is hoped that this technology can be utilized by individuals like the District Agriculturists and Agricultural Fieldmen for salinity control in their counties.

It must be noted that this program is not intended to replace actual field investigations because, only by installing water table wells and piezometers, can flow systems be identified and soil profiles be determined. The main purpose of this program is to assist in the development of controls for salinity on a scale that is warranted by the problem. The program is designed to be terminated at any time with a recommendation that a Dryland Salinity Investigation be carried

out by Alberta Agriculture if a satisfactory conclusion cannot be achieved.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to Wayne Foxall, who developed ASSESS for the Conservation and Development Branch, and Debbie Baart, who incorporated the flow chart system into our program documentation.

DRYLAND SALINITY INVESTIGATION PROGRAM STATUS REPORT

December 1992

Don Wentz[1]

PREFACE

The Dryland Salinity Investigation (DSI) Program is now into its tenth year. There are 358 farm clients as of December 1992 with 440 projects under investigation. Statistics Canada information from the 1991 Alberta Small Area Data is analysed with the DSI program as a base.

INTRODUCTION

The DSI Program has completed it's tenth year in 1992. The Dryland Salinity Investigation Procedures Manual reports that Alberta has 1.6 million acres of farmland affected by salinity.

The 1991 Statistics Canada, Agricultural Profile of Canada-Part 1, asked producers to indicate if they used "Windbreaks and Shelterbelts Planted for Soil Conservation and the Use of Measures to Control Soil Salinity, by Census Division and Census Consolidated Subdivision, 1991". This paper will use Statistics Canada data and relate it to the Dryland Salinity Investigation program. Statistics Canada never asked the producers to indicate what level of control measure being used so we cannot determine if the producers questioned are planting perennial forages in the recharge area or if they are only stabilizing the saline seep with salt tolerant grasses in the discharge area (see Figure 2). In some cases producers consider flex cropping or continuous cropping as a salinity control measure (see Figure 1).

Statistics Canada never segregated producers in the irrigation districts from the census divisions. In these cases where there are large areas of irrigated land it is difficult to determine if the problem is an irrigation or dryland situation.

<u>Region I</u>

In Region I the County of Warner had the highest percentage of producers reporting they "used some means to control salinity" with 44.9%. Producers in the MD of Taber were second with 34.7%. The County of Newell had 32% reporting and the Counties of Forty Mile and Vulcan reported 30% each. The County of Lethbridge had 25% reporting that they practised "some means of salinity control" and the MD of Willow Creek had 22.5%. Cypress had 20% of their producers reporting they use "some measures to control salinity" and the MD of Cardston had 15.9% and the MD of Pincher Creek had 10%.

The overall average for Region 1 is 26.8% of producers indicating they practice some form of salinity control. The census data did not separate dryland and irrigation but based on Dryland Salinity Investigation requests the Counties of Warner, Vulcan and Forty Mile have most of the dryland problems with the MD of Willow Creek fourth. The statistics from Taber, Newell and Cardston reflect more irrigated salinity related problems than dryland. The County of Lethbridge

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reflects a combination of both dryland and irrigated salinity. Pincher Creek has very few salinity problems.

TABLE 1 - STATISTICS CANADA SUMMARY				
	Total No. of Farms	No. of Farms Using Some Means of Salinity Control	Percent	Total DSI Applications
Cardston	710	113	15.9	2
Cypress	1004	206	20	10
Forty Mile	748	222	29.6	39
Lethbridge	1188	297	25	20
Newell	933	299	32	1
Pincher Creek	499	51	10	4
Taber	952	331	34.7	14
Vulcan	855	259	31	54
Warner	607	273	44.9	150
Willow Creek	863	195	27.5	26
TOTALS	8359	2246	26.8	320

The 1991 Statistics Canada Report on farms using some means of salinity control across the region report that 2246 farms or 26.8% of the total of 8359 farms are practising some form of control. The 247 producers who have DSI requests accounts for 14.2% of the producers who indicated they use some means of salinity control practice. Based on extension principles, the DSI program is probably nearing the end of the Early Adaptor phase and entering the Early Majority phase. The demand for technical assistance to locate recharge areas in Region I can therefore be expected to remain strong or even increase in the future (see Table 1).

<u>Region II</u>

Region II has an overall average of 14.8% of producers using measures to control salinity from the Census data. Wheatland (Strathmore) with 28% has the largest number of producers using some means of salinity control. Wheatland is also a major part of the Western Irrigation District which has a severe salinity problem. Starland (Drumheller) has 23%, SA #3 (Oyen) has 20% and Kneehill (Threehills), Rockyview (Airdrie) and SA #2 (Hanna) has about 16% each. There is little salinity in Foothills which reported 7%, Mountain View which reported 8%, and Calgary which reported 5%. The 1991 Statistics Canada data indicates that of the 1245 producers in Region 2 who use "some means of salinity control", 5.2% have requested assistance in locating their recharge site by applying for a Dryland Salinity Investigation (see Table 7). This would tend to suggest that Region II is still in the Early Adoption phase of utilizing vegetative management for reclamation and control of dryland salinity (see Table 2).

TABLE 2 - STATISTICS CANADA SUMMARY				
	Total No of Farms	No. of Farms Using Some Means of Salinity Control	Percent	Total DSI Applications
Special Area 2	571	89	15.9	4
Special Area 3	650	130	20	6
Bighorn	-	-	-	-
Kneehill	989	160	16	11
Starland	462	106	22.9	12
Foothills	1312	100	7	3
Mountain View	1784	153	8.5	3
Rocky View	1524	238	15.6	16
District 15	120	4	3.3	0
Wheatland	953	265	27.8	10
TOTALS	8365	1245	14.8	65

Region III

Region III has 10% of the 11,244 producers reporting that they use "some means of salinity control". The County of Paintearth (Castor) has 24.7%, Special Area #4 has 21%, the County of Flagstaff (Sedgewick) has 18.3% and County of Stettler has 15.4% of their producers indicating they use "some means of salinity control". The County of Camrose has 14.3% of their producers indicating they use "some means of salinity control". Region III has 21 DSI requests to date accounting for 1% of the producers who practice some means of salinity control. This would indicate that Region III is in the very early adoption stage of vegetative management for salinity control (see Table 3).

TABLE 3 - STATISTICS CANADA SUMMARY				
	Total No. of Farms	No. of Farms Using Some Means of Salinity Control	Percent	Total DSI Applications
Flagstaff	996	183	18.3	9
Paintearth	525	130	24.7	0
Stettler	907	140	15.4	2
Ponoka	1332	57	4	1
Camrose	1419	204	14.3	8
Red Deer	1795	163	9	-
Lacombe	1327	81	6.1	-
Clearwater	1227	30	2.4	-
Wetaskiwin	1352	71	5.2	-
Special Area 4	364	77	21	1
TOTALS	11244	1136	10	21

Region IV

TABLE 4 - STATISTICS CANADA SUMMARY				
	Total No. of Farms	No. of Farms Using Some Means of Salinity Control	Percent	Total DSI Applications
Provost	563	111	19.7	1
Wainwright	650	87	13	3
Vermilion	1412	213	15	5
Beaver	1035	191	18.4	5
Lamont	1152	141	12.2	7
Minburn	878	98	11.1	1
St. Paul	953	43	4.5	1
Two Hills	807	63	7.8	2
Bonnyville	657	24	3.6	-
Smokey Lake	672	30	4.4	-
Lac La Biche	785	22	2.8	-
TOTALS	9564	1023	10.6	25

Region IV has 10.6% of the 9,564 producers reporting salinity control measures were used. The MD of Provost has 19.7% and the Counties of Beaver and Vermilion has 18.4% and 15% respectfully. The MD of Wainwright has 13%. The County of Lamont has the most DSI requests but has 12.2% of their producers indicating "some means of salinity control" is practised on their farm (see Table 4).

The Statistics Canada data indicates that the southern part of the region has more salinity problems than the north. This is reflected in the number of DSI requests from the southern part of the region as compared to the north. Region IV has 25 DSI applications accounting for 2.4% of the 1,023 producers who practice some means of salinity control. Region IV is in the early adoption stage of utilizing vegetative management for salinity control (see Table 7).

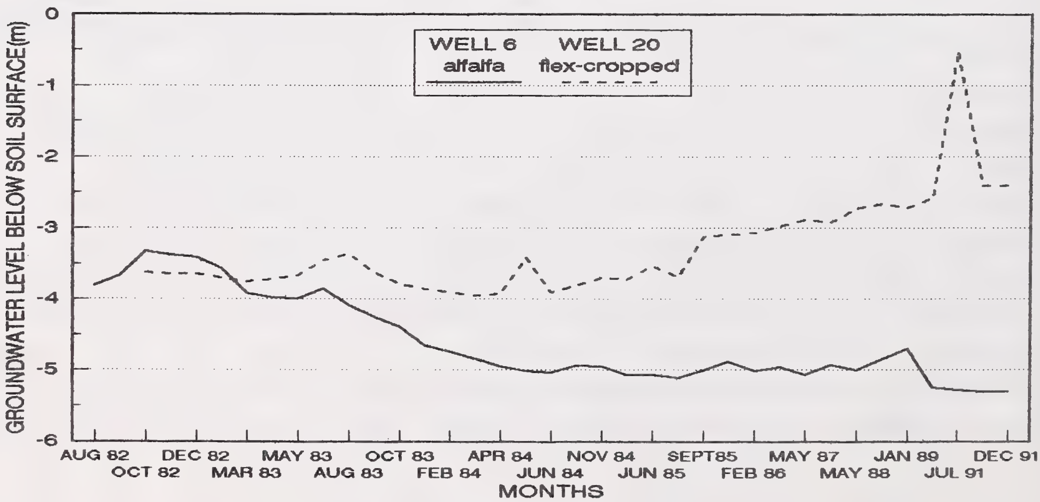

Chart 1. Summary of WTW levels for # 6 and 20.

Region V

TABLE 5 - STATISTICS CANADA SUMMARY				
	Total No. of Farms	No. of Farms Using Some Means of Salinity Control	Percent	Total DSI Applications
Leduc	1595	52	3.2	1
Lac Ste. Anne	1200	31	2.5	-
Slave Lake	672	30	4.4	-
Ft Assiniboine	327	6	1.8	-
Evansburg	782	8	1	-
Brazeau	619	10	1.6	-
Barrhead	993	33	3.3	-
Westlock	1120	49	4.3	-
Thorhill	691	34	4.9	-
Sturgeon	1150	61	5.3	-
Athabasca	925	28	3	-
Parkland	1145	21	1.8	-
Strathcona	889	37	4.1	-
TOTAL	12108	400	3.3	1

Region V has few salinity problems indicated by the fact that only 3.3% of the producers are practising any means of salinity control. This is also reflected in the fact that Region V has only 1 request for an investigation (see Table 5).

Region VI

TABLE 6 - STATISTICS CANADA SUMMARY				
	Total No. of Farms	No. of Farms Using Some Means of Salinity Control	Percent	Total DSI Applications
Grand Prairie	1526	81	5.3	5
Peace	254	23	9	1
Smokey River	597	36	6	1
Fairview	342	15	4.3	-
Valley View	880	38	4.3	-
High Prairie	1049	32	3	-
Wanham	384	25	6.5	-
Spirit River	884	43	4.8	-
Worsley	622	20	3.2	-
Manning	765	32	4.1	-
Fort Vermilion	670	38	5.6	-
Smokey River	597	36	6	-
TOTAL	8570	419	4.9	7

Region VI has few dryland salinity problems to contend with as indicated by the few requests for assistance and by the fact that only 4.9% of the producers are using some means of salinity control (see Table 6).

TABLE 7 - STATISTICS CANADA SUMMARY						
	Total No. of Farms	No. of Farms Using Some Means of Salinity Control	Percent of Total	Total DSI Applicatio ns	Percent of controlwith DSI	Potential DSI clients
Region I	8359	2246	26.8	320	14.2	1926
Region II	8365	1245	14.8	65	5.2	1180
Region III	11244	1136	10	21	1.8	1115
Region IV	9564	1023	10.6	25	2.4	998
Region V	12108	400	3.3	1	0.2	399
Region VI	8570	419	4.9	7	1.6	412
TOTALS	58210	6469	11.1	439	6.8	6030

RESULTS AND CONCLUSIONS

There are 358 client requests for 440 salinity investigation completed to date across the Province. The Statistics Canada data would indicate that the DSI Program has attracted 6.8% of the potential producers with a salinity problem. The remaining 6,030 producers that are practicing some means of salinity control are a reflection of the interest in salinity control accross the Province. It would also be interesting to know of the 58,210 producers, how many have salinity problems and are not using any means of control . The interest in salinity control can also be noted in the fact that Statistics Canada asked the question of producers on their most recent questionere. Some efforts should be made to reach these producers and determine the state of their controls and to encourage controls in the recharge as well as the discharge. It may be possible for Statistics Canada to expand their questions related to dryland salinity in their next survey.

As Dr. Paul said there can be no permanent control of a saline seep until the recharge area is controlled.

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Figure 1. A developed saline seep in a field that is flex cropped

Figure 2. A seep near Calgary planted to salt tolerant grasses

ROOTING DEPTH AND SOIL WATER USE OF TEN VARIETIES OF ALFALFA IN SOUTHERN ALBERTA

D. Wentz, B. Read, V. Sawchuk[1]

INTRODUCTION

In 1990, a study was initiated to determine which alfalfa cultivars are the most suitable for the vegetative control of dryland salinity (Miller and Read). Suitability was based on yield, rooting depth and soil water use. Following two years of study, Beaver alfalfa consistently ranked number one of the ten varieties tested. Indications are, however, that these results may be applicable only for the soil zone in which they were determined; in this case, the Dark Brown zone. As a result, the study was duplicated in the Brown zone with the same objectives in mind. The first years results (1992) are presented in this report.

METHODS

The study site is located on private land near Bow Island, Alberta. An existing alfalfa variety trial containing the same cultivars as those tested in the 1990-1991 project was used for the 1992 edition of the study.

Ten alfalfa varieties were replicated three times providing a total of thirty alfalfa plots as well as three fallow treatments (Table 1). In each plot a 4 m deep access tube was installed to allow soil moisture to be read at depth using the neutron scatter technique. At each of the four corners of the plot area, a water table well was located to monitor groundwater movement under the plots. A rain gauge was also situated on site. Data collection began in April of 1992 and continued bi-weekly through September of that year.

The soil in each plot was sampled and analyzed for particle size and routine chemistry. Results indicated a generally uniform clay loam textured soil with a mean 0-150 cm electrical conductivity of 4.7 dS/m. An EM-38 survey was performed in the plot area to further determine soil salinity levels. A salinity contour map of raw EM values was prepared from this information (Figure 1).

Rooting depth and soil water use for each alfalfa variety was determined from a graph of soil moisture versus depth for each alfalfa cultivar and fallow plot (Figure 2). Rooting depth was determined on the graph by the intersection of the alfalfa and fallow curves. Soil water use was calculated as the area between the two curves from a depth of 25 cm to the depth of rooting. The 1992 results from this study are reported as mean yield, rooting depth and soil water use of three reps. Mean values of soil moisture for the three fallow plots were used in all moisture use and rooting depth determinations.

At the completion of year two of this study, each plot will be cored and a visual examination for roots will take place.

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VARIETY	TYPE	ROOT TYPE	HARDINESS
Rambler	Dryland	Creeping	Excellent
Spredor II	Dryland	Strongly Creeping	Excellent
Pioneer 524	Standard	Tap	Good
Drylander	Dryland	Strongly Creeping	Excellent
Algonquin	Standard	Modified Tap	Medium
Trumpetor	Flemish	Modified Tap	Fair
Beaver	Standard	Deeply Rooted Modified Tap	Medium
Rangelander	Dryland	Strongly Creeping	Excellent
Pacer	Flemish	Modified Tap	Fair
Heinrichs	Dryland	Moderately	Excellent

Table 1. Ten alfalfa cultivars used in this study

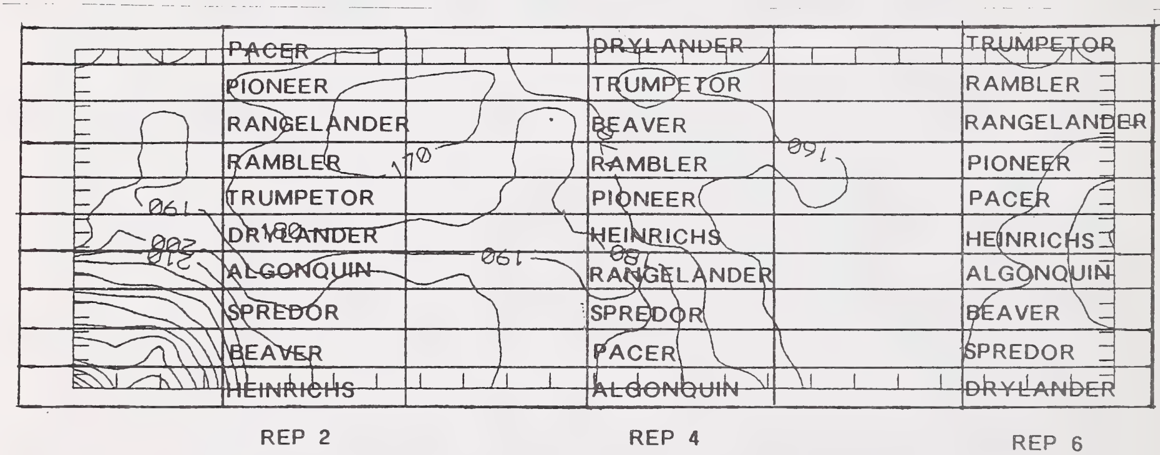

Figure 1. Plot design with EM-38 salinity contours

RESULTS

The performance of each alfalfa variety was ranked from one to ten (one being best) according to yield, rooting depth and soil water use. In addition, each variety was rated for overall performance by totalling each individual ranking (Table 2). Evaluation of each alfalfa variety based on the three variables revealed Rambler to be the best cultivar overall, even though Beaver yielded 8.5% higher, Algonquin rooted 4.6% deeper and Rangelander used 4.3% more soil water.

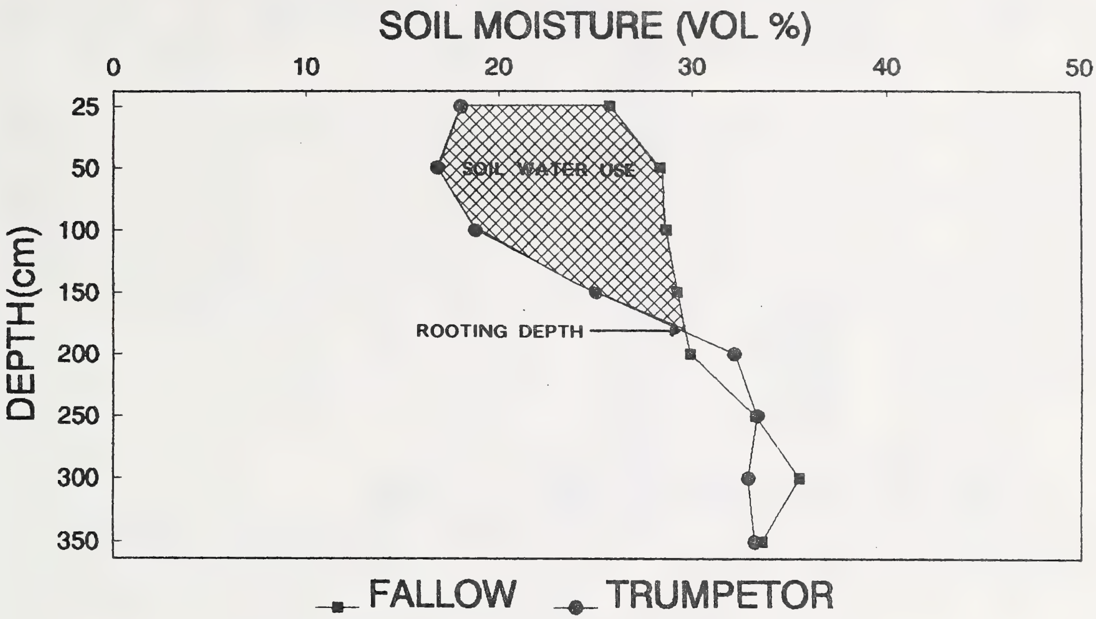

Figure 2. Example rooting depth and soil water use graph

It should be noted that the reported soil water use values may appear deceptively low for the yields produced since they are based on plant use from 25 cm to the calculated depth of rooting. In this case, where groundwater is available for crop use, a significant portion of the water required by the alfalfa may come from this source; the quantity is difficult to determine. It was not the intent of this study to determine yield based on specific soil water use, but rather to compare the performance of one alfalfa variety against another based on certain criteria. Since the entire plot area was subject to the same shallow groundwater, its influence will not be considered of consequence. Ideally, future studies of this nature would take place on land where the groundwater was deeper and not a concern.

Groundwater levels under the plot area remained relatively constant throughout the season. Significant fluctuations in water table depths appear to correspond to the occurrence, or lack of major rainfall events (Figure 3).

Calculated rooting depths ranged in the vicinity of the groundwater levels, indicating that the alfalfa is rooting into the saturated zone above the water table and penetrating no further. It is likely that over time deeper water tables may result in deeper rooting depths to a maximum depth of upward water transport by the plant.

SUMMARY AND CONCLUSION

Two seasons of study (1990 and 1991) in the Milk River area determined Beaver alfalfa to be the cultivar with the best overall combination of yield, rooting depth and soil water use. As such, Beaver was recommended as the cultivar of choice as a vegetative control for dryland salinity. Preliminary results from studies in the Bow Island area (1992) have shown an entirely

VARIETY	OVERALL RANKING	YIELD Kg/ha	RANKING	ROOTING DEPTH m	RANKING	SOIL WATER USE (cm)	RANKING
Rambler	1	3509	3	2.08	2	8.9	2
Rangelander	2	2908	6	2.01	3	9.3	1
Beaver	3	3832	1	2.00	4	7.8	7
Heinrichs	4	3231	5	1.97	5	8.5	4
Drylander	5	3638	2	1.83	7	8.2	6
Algonquin	6	2113	8	2.18	1	7.7	8
Pioneer	7	2843	7	1.94	6	8.3	5
Trumpetor	8	1828	10	1.82	8	8.6	3
Pacer	9	3379	4	1.43	10	7.2	10
Spredor	10	2068	9	1.44	9	7.6	9

Table 2. Yield, rooting depth and soil water use

different ranking for the ten varieties studies. That is, Beaver now placed third and Rambler ranked number one from a previous position of seventh. A second season of study (1993) is planned at the Bow Island site to verify the 1992 findings.

It is likely that the environmental conditions associated with each particular soil zone affect the performance or suitability of the various alfalfa cultivars for that area. A certain variety which does well in one area may not perform as well in another. It may, therefore, be important to evaluate the varieties on a zonal basis and develop recommendations in that regard. Plans to duplicate this study in other regions of the province are being considered.

ACKNOWLEDGEMENTS

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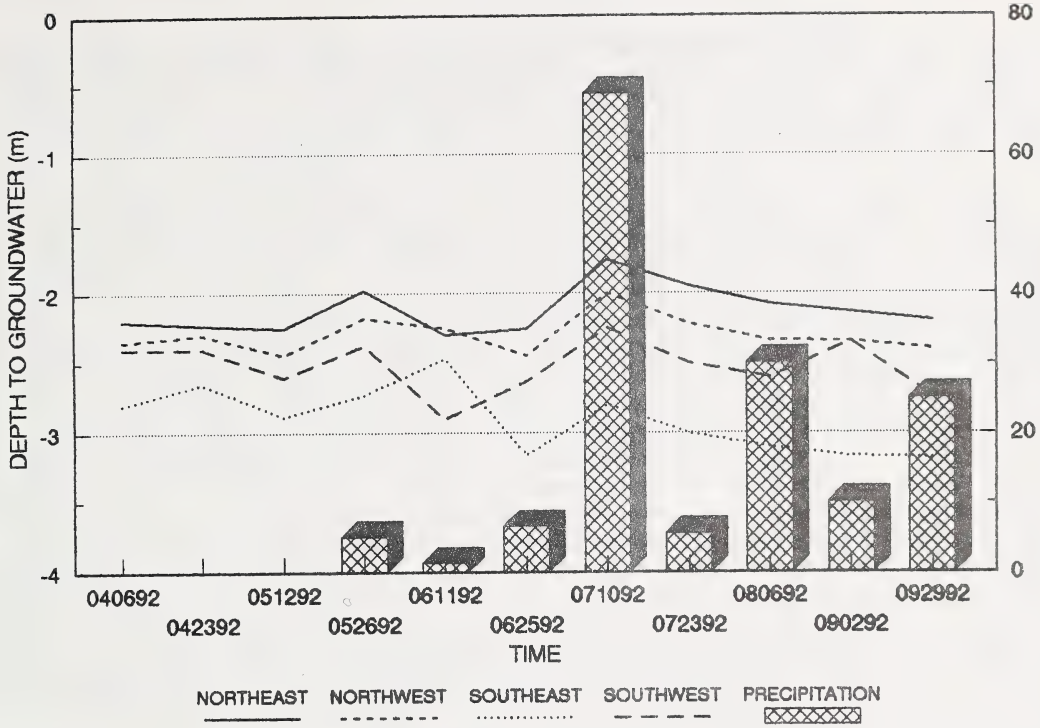

Figure 3. Seasonal groundwater movement and precipitation

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CANOLA AND CONSERVATION TILLAGE

Thomas L. Jensen[1]

INTRODUCTION

Many cereal producers have adopted conservation tillage practices and understand their benefits in reducing soil erosion. Most canola producers do not use these soil conservation practices and as a result many fields prepared for seeding of canola are subject to soil erosion. Due to the small seed size of canola most producers try to create a fine, well packed, seedbed. This often requires numerous tillage operations to be done followed by harrowing and packing. Decreasing the number of tillage operations would prevent unnecessary moisture evaporation and also reduces the risk of erosion by wind and/or water.

One challenge with conservation tillage production of canola is incrop weed control. The no-tillage form of conservation tillage does not facilitate the use of pre-plant soil incorporated herbicides such as Trifluralin. The grower is restricted to a pre-seeding non-selective herbicide application such as Roundup and then use appropriate selective in-crop herbicides for some weed species.

Canola can be grown with reduced tillage or no-till seeding and yields may actually increase due to decreases in evaporative losses common after intense tillage. Operating costs should decrease with less tillage as less fuel, labor and machinery is needed to prepare the seedbed. Herbicide costs will rise but the savings from the decreased tillage costs should offset the increased cost of herbicides.

The objectives of this project were to assess the feasibility of growing canola using conservation tillage (minimum and no-tillage or direct seeding). Also to determine whether five different cultivars of argentine (B napus) canola would grow similarly under the three tillage systems.

METHODS

The experiment took place at two sites in central Alberta, Strome and Calmar. Each site consisted of four replicates. During the first two years (1989, 1990) there were seven tillage treatments in total analyzed in randomized complete blocks. The treatments ranged from no-tillage to extreme tillage. After the second year it was noticed that all the tillage types resulted in similar yields. As the seven different levels of tillage showed little difference in yields the experiment was simplified to the three contrasting tillage types (no-till, minimum, and conventional). Five suitable Argentine cultivars (Alto, Bounty, Hyola, Legend, and Westar) were seeded the last two years. The five cultivars were selected to see if there was an observable interaction between tillage type and cultivar. The cultivars chosen varied from the long-time standard Westar to the hybrid Hyola 401.

This experiment used a split block design. Each replicate or block was split into five canola cultivars in one direction and split into the three tillage types perpendicular to the variety orientation. The order of the cultivars and the tillage type were randomly assigned. Each site received a blanket fertilizer application up to a level of 80 kg/ha N and 30 kg/ha P205. Neither site needed

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other macro or micronutrient applications as determined from soil test results. Excel herbicide was sprayed over the entire site at the Strome Site for thistle control. Trifluralin (in the year 1989) and ethyl fluralin in the years 1990, 1991 and 1992) were applied to the conventional and minimum tillage treatments. The sites were seeded using a John Deere 750 series seed drill. Square meter yield samples were taken each fall at harvest time.

RESULTS AND DISCUSSION

Over the four years of the project, seven site years of results were gathered, tillage types resulted in similar yields for five of the seven site years. The exceptions were the no-till treatments in 1992. At the Calmar site lower no till yield was a result of competition by weeds. Calmar was seeded earlier than other years on May 1, 1992. The spraying of Roundup was found to be ineffective in controlling later emerging perennial weeds. This resulted in a large population of Perennial Sow Thistle and Canada Thistle on the no-till treatments. The other two tillage treatments experienced less of a weed problem. The Canola site had been seeded later, usually the second or third weeks of May in the previous years. At these later seedings the preceding Roundup application resulted in adequate suppression of the above mentioned weeds. it is reasonable to expect that if a selective application of Lontrel had been used at Calmar in 1992 as had been used at Strome, the perennial thistles would have been adequately controlled and the yield of no-tillage canola at Calmar would have been similar to the minimum and conventional treatments.

In contrast the dry growing conditions at the Strome site in 1992 resulted in a significant yield increase from using no-tillage seeding. This was due primarily to the moisture conserving benefit of no-tillage practices.

The average canola yields by tillage treatment at the Strome site for the years 1990, 1991, and 1992 are as follows :

Year	Tillage Type	Yield kg / ha	(bu./acre)	Non-significant range
1990	no-till	1744	(26.2)	a
1990	minimum	1722	(25.8)	a
1990	conventional	1440	(21.6)	a
1991	no-till	1290	(19.4)	a
1991	minimum	1400	(21.0)	a
1991	conventional	1240	(18.6)	a
1992	no-till	1285	(19.3)	a
1992	minimum	897	(13.5)	b
1992	conventional	975	(14.6)	b

The average canola yields and by tillage treatment for the Calmar site for the years 1989, 1990, 1991, 1992 are as follows:

Year	Tillage Type	Yield kg / ha	(bu./acre)	Non-significant range
1989	no-till	1116	(16.7)	a
1989	minimum	1190	(17.9)	a
1989	conventional	970	(14.6)	a
1990	no-till	1735	(26.0)	a
1990	minimum	2015	(30.2)	a
1990	conventional	1544	(23.2)	a
1991	no-till	1353	(20.3)	a
1991	minimum	1593	(23.9)	a
1991	conventional	1547	(23.2)	a
1992	no-till	1073	(16.1)	b*
1992	minimum	1763	(26.5)	a
1992	conventional	1689	(25.4)	a

* Lower yields of the no-till treatment largely due to inadequate control of thistles (Perennial Sow Thistle and Canada Thistle).

Including the five different canola cultivars at the Strome and Calmar sites in 1991 and 1992 showed that there was no significant interaction between tillage system and cultivar. In most cases the better yielding canola under conventional was also better yielding under minimum or no-tillage. This emphasizes the point that yields of canola under conservation tillage will not be radically different from conventional practices.

CONCLUSIONS

This project showed that canola yields similarly using conservation tillage practices or conventional tillage. Yields were not significantly different whether the tillage was conventional, minimum or no-till. If proper weed control is accomplished no-tillage or direct seeding has the potential to allow moisture to be conserved and could result in slightly higher yields. This was the case at Strome during 1992 where the no-till treatments had an average yield of 1285 kg/ha, the minimum treatments averaged 897 kg/ha and the conventional treatments averaged 975 kg/ha. The tillage treatments caused some of the soil moisture to evaporate whereas the no-till treatments resulted in less soil disturbance and more moisture was available for plant use. When moisture is adequate the yields did not vary much between tillage types. Under no-till production of canola the producer must be aware of the weeds present on the field. Growers who routinely seed canola using no-tillage practices stress the importance of broadleaf weed control in the non-canola years of their crop rotation. They use the year of canola to achieve grassy weed control (eg.use Excel or Poast herbicides) and perennial thistle control (eg. Lontrel).

No-till production of canola is an excellent erosion prevention measure. Less tillage leaves the soil less susceptible to erosion by wind and/or water. As new selective herbicides allowing broadleaf weed control in canola are developed the use of no-tillage production of canola will increase. Even now with careful weed management acceptable yields of canola are achieved using minimum or no-tillage canola production.

THE EFFECTS OF FIELD SHELTERBELTS ON SOIL MOISTURE AND CROP YIELD IN ALBERTA, IN 1992

J. Timmermans, C. Sprout, I. Laslo[1]

INTRODUCTION

Reduced soil erosion, reduced wind damage of crops, and higher levels of available moisture due to snow trapping and reduced evaporation are the major agronomic benefits provided by field shelterbelts. In spite of these expected benefits, shelterbelts are still a long term undertaking, and one which requires inputs of time and money years before benefits are realized. Research from many parts of the world has shown that field shelterbelts result in higher yields in the protected zone to more than offset the costs and losses in yield.

The objective of this on-going project (initiated in 1990) is to develop and improve a database of information on the effects of shelterbelts in Alberta. This information can then be used to support the decision making by farmers in their conservation management using field shelterbelts.

METHODS

Crops were sampled from seven fields near shelterbelts in 1992. These sites were located near Vulcan, Delia, Cereal, Sedgewick, Wainwright, and Barrhead. Three of the belts were single row caragana; one multiple row mixed deciduous trees and shrubs; one single row willow; one single row of spruce; and a multiple row mixed coniferous and deciduous trees. Four belts are orientated E-W and three belts N-S. Spring wheat was planted at five sites, barley at one site, and oats at another.

At four of the field sites soil moisture samples were taken in the spring just prior to seeding. These were the Pincher Creek, Vulcan, Delia and Cereal sites. Sampling locations were along a line perpendicular to the belt on the leeward side. Each sampling location was a multiple of the height of the belt (h) as measured from the centre of the belt as follows: 1h, 2h, 3h, 5h, 10h, 15h, 20h, and 30h. The 30h site is beyond the effective range of influence of the shelterbelt, and therefore assumed to represent the open field normal for soil moisture and crop yield. Three replicates 20 m apart were taken at each field site. The sampling grid was the same for both crop yield and soil moisture was the same at those sites where both were sampled.

The soil texture and crop available moisture (AM) in mm (to a depth of 120 cm) was determined for each sampling location. The percent of open field available moisture was also calculated to allow combining of all the field sites to produce one average moisture response curve for the 1992 data.

At all seven field sites two square meters of crop were harvested at each of the locations described for soil sampling. Grain weights were measured for each site and absolute and relative grain yields were calculated. Because the total number of sites is small, the results were not separated to comare the effects of crop variety, shelterbelt orientation, or shelterbelt species. However, it is expected that as the number of site years becomes larger, the effects of these variables on crop yield can also be determined.

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RESULTS

The data collected from the various sites in 1992 were combined and the averages are shown as a percent of open field moisture and and open field yield (Fig. 1). The yield curve shows an increase in yield from 1h to 15h and then a decline to open field level at 20h. At most sites there was no yield at 1/2h because sampling sites were measured from the center of the belts. The largest average increase was at 2h with a 55 % increase over open field yield at 30h. Statistically (at the 5 % level), the relative yields in the 1h to 15h area are significantly higher than at 30h. The moisture curve shows a dramatic and statistically significant increase in available moisture in the 1h to 10h area over that at open field with a maximum increase of 4 1/2 times at about 2h. The average increase in available moisture for the area of influence (0h to 20h) over that in the open field is 175%.

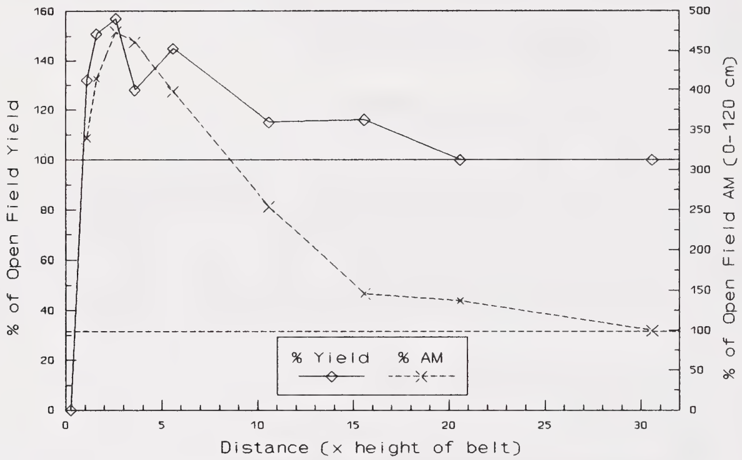

Fig. 1. Shelterbelt effect on spring soil moisture and crop yield in 1992, from seven field sites.

A comparison of the average results of yield response to field shelterbelts for 1990, 1991, and 1992 are shown in Fig. 2. It is apparent that different years produced different response curves. The average yield increase in the 0h to 20h area over that in the open field was 11 %, 4 %, and 21 % for 1990, 1991, and 1992 respectively. In 1991 low snow fall levels in general and adequate growing season moisture produced a low response. A drier growing season in 1990 and significant snow trapping the previous winter at some sites elevated the yield curve. In 1992 soil moisture was severely limiting at a couple sites particularly at Wainwright. As a result the extra soil moisture by the belt produced wheat yields over 60 bu/ac. compared to less than 20 bu/ac. in the open field. Removing the Wainwright data from the data base for 1992 would bring the average yield increase down to aproximately 10%.

CONCLUSION

The results to date show field shelterbelts increase soil moisture and crop yield. Improved yield near field shelterbelts is an incentive for farmers to plant trees in field shelterbelt systems. It is also evident the effectiveness

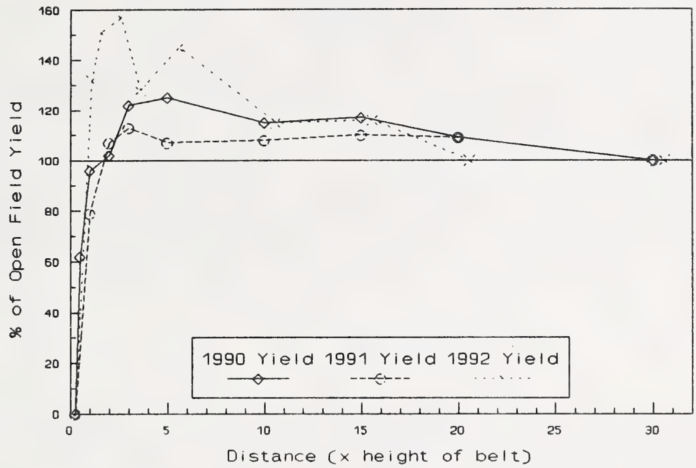

Fig. 2. Mean shelterbelt effect on crop yield in 1990 (6 sites), 1991 (8 sites), and 1992 (7 sites).

of belts may vary from year to year depending on snow trapping and growing season precipitation. There are many other factors that need to be evaluated such as belt orientation, belt type (height, width, density), soil texture, and type of crop. Continued research will produce a larger database to better evaluate these factors. This information will provide stronger bases for economic evaluation of field shelterbelts under Alberta conditions.

FIELD SHELTERBELT DEMONSTRATION ACTIVITIES

J. Timmermans, C. Sprout, I. Laslo[1]

INTRODUCTION

Continuing activity in demonstration of establishing field shelterbelts is one of the functions of the wind erosion / field shelterbelt unit of the Conservation and Development Branch staff at Airdrie. The primary objectives of this work are to demonstrate the design, site selection, site preparation, planting and weed control practices required for successful establishment. Further benefits of this work are on the job training through hands-on experience for professional and technical staff, and for field and extension staff involved in field shelterbelt programming at the municipal level.

METHODS

Six sites are currently being used as demonstration sites. These are near Acme, Blackie, Delia, Strathmore and Beiseker (2). Each of these was chosen for its highly visible location, a keen interest expressed by the landowner, and also by the local Agricultural Service Board and extension staff.

The equipment used in all aspects of this demonstration work include a tractor (40 hp), a 6 foot tandem disc, a six foot cultivator, a three point sprayer equipped with a hand nozzle, and 12 foot boom, an air flow assisted granular herbicide applicator mounted on the tandem disk, a 20 foot tandem axle flat bed trailer, and a 1 ton truck to pull it. This truck is also equipped with a soil sampler which is used to take soil samples of the rooting zone to assess soil moisture.

A transit, chain and portable radios are the tools used to locate the future shelterbelts in the field. For site preparation, a strip six feet wide is cultivated with a tandem disc of that width. Trifluralin is then applied either in fall or in spring before planting. A six to eight foot strip on each side of the newly planted shelterbelt is then dept weed free by cultivation.
In-row weed control has been accomplished by both hoeing, and by application of herbicides, as site conditions indicated.

RESULTS

At all demonstration sites, the opportunities for local publicity are exploited. Local newspapers and major television coverage is constantly pursued. At one of the current sites, arrangements made between the landowner, branch staff and a local Boy Scout Troop have resulted in a 2.5 mile system of shelterbelts which they helped to plant, and which they have "adopted". The Boy Scouts have promised to work to keep the trees at this site weed free by hoeing up to three times per year. The positive public relations from this project alone has resulted in several calls from leaders of youth groups about the possibilities of doing the same. A further project involving the Junior Forest

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Wardens is planned for this spring.

Weed control is the most difficult but crucial part of successful establishment. At some of the above sites, weed control by hoeing soon proved to be impractical. Because cruciferous weeds are not controlled by trifluralin, and some of our sites had high levels of infestations, the need for an applicator which could apply soil applied herbicides in the planted row became apparent. In 1992 a sprayer was constructed in the shape of an inverted U which could straddle the young trees. Using offset nozzles, linuron could now be applied in a directed spray to avoid contact with the leaves of the trees. Linuron applied at 1.8 litres per acre in 180 litres of water provided season long control of broadleaf weeds at an affordable price. One of the co-operators was so pleased with these results that he decided to continue planting shelterbelts on his land after he had earlier stated that he would not.

A herbicide registered for the control of most grassy weeds is dichlobenil (Casoron). Thus far, it has been difficult to apply in a narrow band because of its light granular nature. Because of its higher cost we are currently recommending that it be used on the problem areas only.

Herbicide drift from products used in the adjacent crop can severely damage field shelterbelts. Green ash are susceptible to phenoxy (2,4-D), and nitrile (bromoxynil) herbicides. We urge cooperators to use products less harmful to the trees such as sulfonylureas (Refine, Extra or Ally) to avoid damaging drift. One cooperator used a sulfonylurea product in a hooded sprayer right up to his green ash seedling, and no visible damage occurred.

Some of the non-chemical agents which can harm shelterbelt seedlings have also been learned. The appetite of rabbits and gophers for Siberian larch and winter feeding by rabbits on Green ash have resulted in the need to apply repelling products such as thiram (Scoot). Thus far, grasshoppers have been the only problem insect pest encountered. The speed at which they can defoliate young caragana or mature ones has been disheartening. Generally however, grasshoppers turn to the trees when the crop ripens, and by that time, defoliation of the trees is not as serious as it would be earlier in the season.

The roots of Siberian larch are shallow and not very substantial. These larch are therefore prone to damage by tillage which is too deep and too close to the seedlings. This has been another lesson learned first hand.

Many questions from field and extension staff have involved weed control and herbicides. In spring of 1992 we compiled all the information available from product manufacturers, labels, and specialists, regarding registered chemicals, rates, methods of application and comparative costs. This information package was distributed to all field and extension staff involved with shelterbelt projects and programs. Furthermore, detailed drawings of the U-boom sprayer were made so that anyone else might do the same, or use as a guide the plans we had used.

CONCLUSIONS

A continuation of a hands-on component of our work with field shelterbelts is crucial to our success in promotion of this conservation management technology. Field shelterbelts are a long term commitment. Constructive advice to assist in successful establishment at the beginning is therefore important. The demonstration aspect of our work fits well with the research projects we undertake to quantify other parameters of field shelterbelts. The experience gained from this work gives staff the credibility and confidence to consult with clients in a positive way.

WIND REDUCTION BY A CARAGANA FIELD SHELTERBELT IN SOUTH CENTRAL ALBERTA, IN 1992

J. Timmermans, C. Sprout, I. Laslo[1]

INTRODUCTION

Field shelterbelts are barriers to the wind, and thus reduce wind velocity, mainly in the downwind vicinity. Wind reduction in turn, results in a number of changes in the characteristics of the micro climate in the protected zone. Each of these differences, and their combined net effect, influences the growing conditions for the crop.

The objective of this project is to measure the following effects of a caragana field shelterbelt:

1. In-leaf and out-of-leaf wind reduction profiles.
2. The wind reduction profiles as influenced by orientation of the belt to the wind direction.
3. The wind reduction profile as influenced by incoming wind velocity.
4. Temperature and relative humidity in the sheltered versus unsheltered zones.

METHODS

The caragana shelterbelt which was the site of the research in 1992 was located near Beiseker, Alberta, on a level, shallow black chernozemic loam (L.L. NW9-28-27, W4). The shelterbelt is a single row, 40 year old caragana belt about 4.25 m high and 6.5 m wide. The belt is dense and uniform and oriented in a N-S direction along the property line (offset about 12 m east of a gravel road). The field leeward and to the east of the belt was in fallow in 1992 and provided an opportunity to set up the monitoring equipment from July 21 to December 8, 1992, and to monitor the site frequently without causing crop damage.

The monitoring equipment consisted of an array of anemometers (met-one, model 014a) placed in a line perpendicular and to the east of the belt. The spacing of the anemometers was a factor of the height of the belt (h) as follows: 1h, 3h, 5h, 7h, 10h, 15h, and 25h. The 25h location is assumed to be out of the range of influence of the belt and therefore represents the open field or unsheltered value. A wind direction sensor (met-one, model 024a) was placed at 25h. Temperature and relative humidity probes (model 207) were installed at 3h and 25h. The 3h location was considered to be near the most sheltered distance from the belt. All sensors were set up at a height of 1 meter from the ground except the wind direction sensor which was placed at a 2 meter height.

All of the sensors were connected to a CR10 datalogger which was programmed to register input every 30 seconds, calculate an average every 10 minutes, and store these values in final storage. The stored values were down loaded twice a week via a notebook computer. All of the data collected while the belt was in leaf was compiled in one database while the out of leaf data was put in another.

Wind reduction or relative wind speeds at the different distances were calculated by dividing those velocities by the corresponding one at 25h. The

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wind direction as measured in degrees was grouped into 16 segments of the compass, each segment included 22.5°. Combined west winds include NW, WNW, W, WSW, and SW winds (270°± 56.25°). Similarly, east winds include 90°± 56.25°.

RESULTS

The average results of the effect of the caragana belt on wind velocity for both in and out of leaf conditions are shown in Fig. 1. Leeward represents the effect of winds originating from the west (270°± 56.25°). The relative wind speed averages exclude all values where the wind speed at 25h was less than 0.5 m s^{-1} (1.8 kmh), which is the threshold value of the anemometer. It is evident that the in-leaf caragana belt was effective in reducing west winds with a maximum reduction of 89 % at 3h and a 90 % recovery of open field velocity between 15h and 25h leeward. The out of leaf belt was not as effective with 68 % wind reduction at 3h, however the protected distance is very similar to the in-leaf. The east winds were reduced about 22% but only out to 3h windward of the belt.

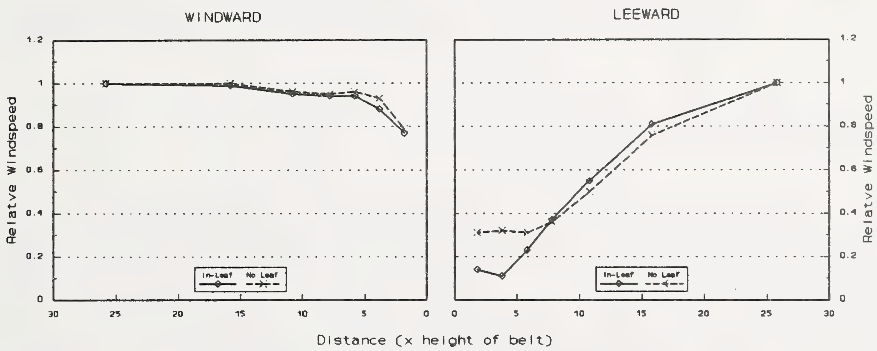

Fig. 1. Relative wind speeds around a single row caragana, both in-leaf and out-of-leaf (windspeeds measured were from the west (270°± 56.25°), and from the east (90°± 56.25°)).

The average open field wind speed during the in-leaf period was 2 m s^{-1} (7.2 kmh) and during the out of leaf period was 2.6 m s^{-1}(9.4 kmh). There were very few strong winds recorded during this project but when the stronger west winds were selected (wind speeds ≥ 4.5 m s^{-1} (16.2 kmh)) it was found that the wind reduction was about 10 % less than the overall average for west winds. This would indicate that the caragana belt was slightly less effective at reducing the higher velocity winds.

Fig. 2 shows how wind direction affects the wind reduction by the shelterbelt. The greatest reduction in wind speed to the lee of the belt occurred when the wind was perpendicular to the belt from the (W ± 11.25°). Wind reduction was nearly the same when winds were from the WNW and WSW. As expected wind reduction was significantly less (by as much as 30 %) when the winds were from the NW and SW, except at the 1h location. As the direction of the incoming wind becomes more oblique to the shelterbelt, the air flows through a greater width and therefore less porous barrier. The protected zone to the lee of the belt is smaller when the winds are oblique than when they are

perpendicular. The protected distance in which wind reduction is greater than 10% is between 15h and 25h for the W, WSW, and WNW winds but only 10h to 15h for the NW and SW winds. There was little difference in wind reduction on the windward side of the belt when comparing various wind directions except at 1h.

The windspeed curves should be equal pairs for the directions NW and SW, and for WNW and WSW, and so on. The variations between these pairs must be due to the natural variation in the characteristics of the living shelterbelt. The differences would diminish as the number of shelterbelt sites increases.

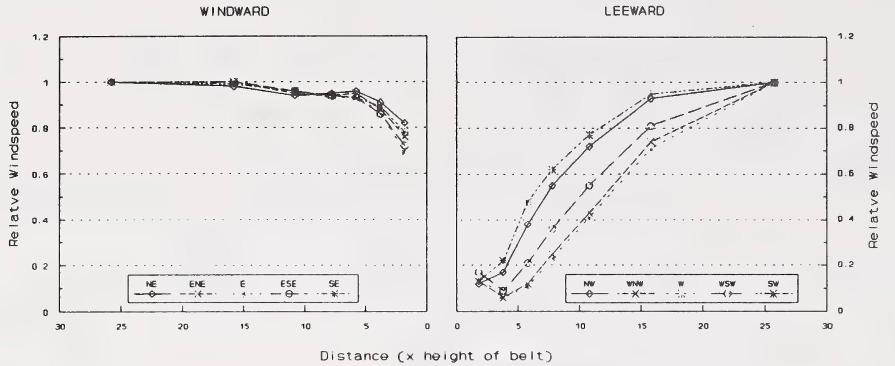

Fig. 2. Relative speed of winds from different directions around an in-leaf caragana shelterbelt.

The air temperature and relative humidity measurements were compiled to produce daytime (8 am - 8 pm) and night-time averages for the sheltered (3h) and unsheltered locations (25h). The average results are for the in-leaf caragana belt and are shown in Table 1. At the sheltered location the air temperature was higher during the daytime and lower at night-time than at the unsheltered location. The higher daytime temperatures would be favourable to high heat unit crops. The lower night-time temperatures may lower respiration as cited by Kort (1988). As expected, the differences in unsheltered and sheltered temperatures is greater when only west winds are considered. The relative humidity in every case is higher at the sheltered location.

Table 1. A comparison of average temperature and relative humidity for sheltered and unsheltered locations behind a caragana shelterbelt

	Temp. °C		% RH	
Parameters	Sheltered	Unsheltered	Sheltered	Unsheltered
Daytime All Winds	17.58	17.32	59.95	58.88
Daytime West Winds	18.25	17.09	56.44	54.81
Night-Time All Winds	8.65	9.05	91.65	87.38
Night-Time West Winds	9.52	10.16	88.70	83.32

CONCLUSION

The caragana shelterbelt was very effective at reducing the west winds. There was a range of wind reduction from 89 % at 3h to 20 % at 15h leeward of the belt. The in-leaf belt reduced the wind more than when it was out-of-leaf but both had about the same protected distance. It is evident and expected that the shelterbelt provides less wind reduction and a shorter protected distance when the winds are more oblique. It also appears that the microclimate is different in the lee of the belt. Further research is required to more accurately define these differences in temperature and relative humidity, and especially the impact of these differences on crop growth.

Future research will evaluate field shelterbelts of other varieties and at additional locations to provide a database of information which will be valuable in making recommendations on shelterbelt designs. Comparison of the wind reduction of high windspeeds is a high priority for further study.

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CHEMICAL QUALITY OF PLANTS, SOILS AND SHALLOW GROUNDWATERS OF SALINE SEEPS IN ALBERTA, 1992

D. Wentz and B. Read[1]

INTRODUCTION

Year three of a four-year study resumed in 1992 to determine if toxic levels of chemicals, in particular trace elements, are present in plants, surface soils and shallow groundwaters within saline seeps in Alberta. The Conservation and Development Branch of Alberta Agriculture recommends seeding salt-tolerant forages in the saline seep as a control measure for soil salinity. If toxic levels of inorganic chemicals are present in shallow groundwaters and soils of saline seeps, then these toxic elements may accumulate in the forages and subsequently in livestock. This may have important nutritional implications for humans.

METHODS

Plant, soil and groundwater samples were obtained from 15 different salinity investigation sites (saline seeps) located within the districts of Cypress, Willow Creek, Cardston, Wheatland, Rockyview, Starland, Kneehill, Acadia Valley and Special Area No. 3. Groundwater samples destined for trace metal analysis were filtered in the field through a 0.45 micrometer filter then acidified, packed in ice and transported to the lab where they were stored at 4°C awaiting analysis. The remaining portion of the groundwater sample was transported on ice to the lab within 48 hours for determination of EC, pH, nitrates, carbonates and bicarbonates. Plant samples were oven dried at 65°C for 24 hours, placed in plastic bags and stored in a deep freeze until analyzed. Soil samples were air dried and stored.

Trace elements in plant, soil and groundwater samples were determined by inductively coupled plasma (ICP) in the Soil and Animal Nutrition Laboratory of the Plant Industry Division of Alberta Agriculture, Edmonton. Trace elements in soil and water samples were also determined by atomic absorption techniques in the laboratory of the Land Evaluation and Reclamation Branch of Alberta Agriculture in Lethbridge. The following chemical constituents were determined in plant, soil and water samples: Ca, Mg, Na, K. SO_4, Cl, Al, Cd, Cr, Cu, Hg, Fe, Mn, Mo, Zn, Pb, Co, As, Se, P, S, B and I.

The following elements or compounds found in the shallow groundwater of the 15 saline seeps exceeded maximum recommended limits for livestock water quality (Environment Canada 1987). These elements or compounds, in decreasing order of abundance, were nitrates = selenium > sulfates> fluorine> molybdenum = lead > cadmium (Table 1a).

The following elements or compounds found in the shallow groundwaters of the 15 saline seeps exceeded maximum recommended limits for irrigation water quality (Environment Canada 1987). These elements, in decreasing order of abundance, were selenium > manganese > arsenic > fluorine > cadmium = molybdenum = lead (Table 1b).

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The following elements found in the plants within the 15 saline seeps exceeded maximum recommended limits for livestock feed and water quality (Alberta Agriculture 1987; Environment Canada 1987). These elements, in decreasing order of abundance, were copper (sheep, cattle) = aluminum = cadmium > molybdenum > selenium > lead > copper (swine, poultry) = cobalt > boron (Table 2).

The following elements or compounds found in the soil (as soil solution extract) within the 15 saline seeps exceeded the maximum recommended limits for livestock water quality (Environment Canada 1987). These elements or compounds, in decreasing order of abundance, were nitrates = selenium > fluorine = sulfates > cadmium = lead (Table 3a).

The following elements found in the soil (as soil solution extract) within the 15 saline seeps exceeded the maximum recommended limits for irrigation water quality (Environment Canada 1987). These elements, in decreasing order of abundance, were selenium > fluorine = arsenic > molybdenum > manganese > cadmium > lead (Table 3b).

SAMPLE	CHEMICAL	% OF SITES > MAX. LIMIT	MAX. LIMIT PPM	TYPE OF GUIDELINE
(a) water	nitrates	100	100	livestock
water	selenium	100	0.05	livestock
water	sulfates	60	1000	livestock
water	fluorine	47	2.00	livestock
water	molybdenum	27	0.50	livestock
water	lead	27	0.10	livestock
water	cadmium	20	0.02	livestock
(b) water	selenium	100	0.05	irrigation
water	manganese	80	0.20	irrigation
water	arsenic	73	0.10	irrigation
water	fluorine	47	1.00	irrigation
water	cadmium	27	0.01	irrigation
water	molybdenum	27	0.05	irrigation
water	lead	27	0.20	irrigation

Table 1. Chemical Quality of Groundwater

SAMPLE	CHEMICAL	% OF SITES > MAX. LIMIT	MAX. LIMIT PPM	TYPE OF GUIDELINE
plant	copper	100	0.5a,-1.0b	livestock
plant	aluminum	100	5.00	livestock
plant	cadmium	100	0.02	livestock
plant	molybdenum	93	0.50	livestock
plant	selenium	80	0.05	livestock
plant	lead	67	0.10	livestock
plant	copper	27	5.00c	livestock
plant	cobalt	27	1.00	livestock
plant	boron	20	5.00	livestock

a = sheep   b = cattle   c = swine & poultry

Table 2. Chemical Quality of Plants

SAMPLE	CHEMICAL	% OF SITES > MAX. LIMIT	MAX. LIMIT PPM	TYPE OF GUIDELINE
(a) soil	nitrates	100	100	livestock
soil	selenium	100	0.05	livestock
soil	fluorine	67	2.00	livestock
soil	sulfates	67	1000	livestock
soil	cadmium	20	0.02	livestock
soil	lead	20	0.10	livestock
(b) soil	selenium	100	0.05	irrigation
soil	fluorine	67	1.00	irrigation
soil	arsenic	67	0.10	irrigation
soil	molybdenum	53	0.05	irrigation
soil	manganese	40	0.20	irrigation
soil	cadmium	27	0.01	irrigation
soil	lead	20	0.20	irrigation

Table 3. Chemical Quality of Soil (sol^n)

CONCLUSIONS

Since this project began in 1990, a total of 72 sites in southern and south central Alberta have been investigated, from which the chemical quality of plants, soils and shallow groundwaters in saline seeps have been determined. Many trace element levels exceeded maximum required limits according to listed guidelines in the three components of this study. These elements all occur naturally and accumulate in saline seeps because of hydrogeological flow patterns. In 1993, the sampling phase of this study will conclude during which time the remaining regions of the province where salinity is a problem will be investigated.

ACKNOWLEDGEMENTS

The authors wish to thank Dan Heany and staff of the SANL (Soils Branch) Edmonton; and Lab Services (LEAR Branch) Lethbridge, for their analytical assistance.

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SNOW TRAPPING USING VARIOUS STUBBLE HEIGHTS AS A SOIL MOISTURE MANAGEMENT TECHNIQUE

A. Howard and B. Read[1]

INTRODUCTION

Insufficient soil moisture is a limiting factor in crop production in all parts of Alberta. Periods of drought in recent years have emphasized this fact, and underlined the importance of all sources of moisture which may be available for crop growth.

Standing stubble has been shown to increase spring soil moisture levels by trapping snow. Research in Alberta (Lindwall and Anderson, 1981), Saskatchewan (Nikolaichuk and Gray, 1986, P.F.R.A., 1986), Montana (Black and Siddoway, 1976, Caprio et al, 1989), and North Dakota (SchneIder et al, 1978) have measured over-winter increases of 25 to 75mm more soil moisture in fields where stubble has been left standing in various ways than in fields where the stubble has been worked down in the fall. These studies however, have mainly occurred in areas where fall conditions are dry and moisture limitations for crop growth are usually severe, such as the Brown and Dark Brown soil zones. Little work has been done to assess the benefits of snow trapping in the Black soil zone, where fall moisture conditions are variable and moisture limitations are considered less severe. The work that has been done has been short term and has shown variable amounts of soil moisture benefit (Maule and Chanasyk, 1988). Some of the reasons that farmers have not readily adopted the practices of leaving standing stubble include concerns about spring field wetness, cooler soil temperatures and whether the yield gains are worth the change in practice. A demonstration project has been developed in the County of Lamont to show the degree of benefit that can be attained from long-term use of standing fall stubble in the Black soil zone, and to address some of the concerns of the farming public regarding moisture, temperature and yield.

The objectives of this study were to demonstrate the differences in snow retention, overwinter soil moisture gain, soil temperature, and yield under three field treatments. The treatments were fall worked stubble, short standing stubble and tall stubble. This report presents the methodology and preliminary results from the first year of the demonstration project. It also includes data from a preliminary test at the site during 1991.

METHODS

On the Rick Anderson farm (SW 28-55-19-W4) in the County of Lamont, a test site was established to demonstrate the snow trapping ability of stubble at various heights. The soil at the site was generally a non-saline loam to clay loam textured till. The slope class was "nearly level" (1%) with a southwest aspect.

In 1991, three treatments were established running the length of the quarter and comprising an area of about 15 hectares each (Figure 1). The treatments were designated "tall" stubble (35 cm high), "short" stubble (10 cm high) and "alternate" stubble (10-35 cm high). The alternate stubble height treatment was

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a combination of short (10 cm) and tall (35 cm) stubble running in alternate strips. Snow depth was measured manually on six occasions at three locations in each treatment beginning December 5, 1991 and concluding February 26, 1992. Data from this study was used for development of a more detailed study commencing in 1992.

Drought conditions during the 1992 growing season resulted in poor crop growth. Consequently, the barley crop was stunted, making it difficult to establish treatments with significant differences in stubble height. As such, only two treatments were used, "tall" stubble (15 cm) and "short"stubble (5 cm). A cultivated treatment was also established. The "tall" treatments contained stubble at the height which remained after direct combining, while the "short" treatments contained standing stubble which had been mowed, simulating a swathed field.

Each treatment was instrumented with a nest of soil temperature probes installed at 5, 10, 25 and 50 cm. Knowledge of soil temperature is of particular importance in the spring when the soil thaws and moisture infiltration occurs. Also in each treatment, three sampling sites were established for the gravimetric determination of soil moisture at 0-30, 30-60, 60-90 and 90-120 cm depth increments. To measure precipitation, a tipping bucket rain gauge and a Nipher snow gauge were located on site. Snow measurements in the winter of 1992-93 began on November 18 and continued throughout the season.

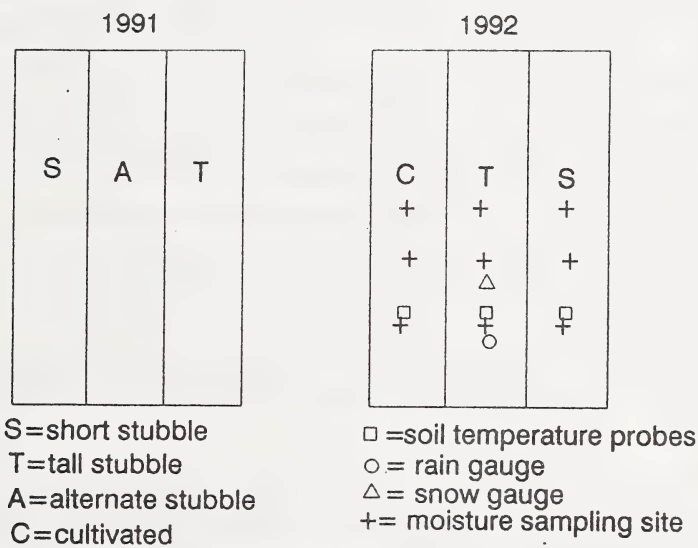

Figure 1. Plot plan showing instrumentation (nts).

RESULTS

Snow depths are presented according to treatment as a mean of the three measurement sites on the date of sampling (Table 1).

Whether on an individual treatment basis or when combined within the

"alternate" treatment, "tall" stubble consistently trapped more snow than the "short" stubble. Snow trapped in the "short" stubble during the 1992-93 winter (based on limited data available at the time of printing) was on average only marginally deeper than that trapped in the cultivated treatment. This observation emphasizes the need to increase stubble height in order to maximize snow retention.

Soil moisture, on a treatment basis, is available only for the fall and winter of 1992 and 1993 (Table 2). Fall moisture levels are not a reflection of the snow trapping ability of a particular treatment, however, winter values may reflect moisture infiltration from early winter snow melt. In that regard, soil moisture levels under tall stubble show the greatest fall to winter increase.

DATE	TALL STUBBLE	SHORT STUBBLE	ALTERNATE STUBBLE		CULTIVATED
			TALL	SHORT	
Dec 05/91	34.7	22.2	39.5	20.8	
Dec 19/91	27.7	10.5	32.9	9.5	
Jan 08/92	32.6	22.4	38.4	23.3	
Jan 22/92	22.6	10.7	21.2	12.4	
Feb 12/92	18.9	10.0	17.7	10.8	
Feb 26/92	21.9	11.7	21.7	13.2	
Nov 18/92	6.7	4.3			3.3
Jan 06/93	21.8	13.4			14.1
Jan 29/93	21.0	10.0			11.0

Table 1. Snow depths (cm) according to treatment

TREATMENT	FALL (Oct 7/92)	WINTER (Jan 20/93)	GAIN
Mowed stubble	165	170	5
Tall stubble	140	162	22
Cultivated	139	148	9

Table 2. Soil moisture mm (0-120 cm depth) according to treatment

Winter soil temperatures, again on a treatment basis, appear to reflect the insulating ability of the snow cover (Table 3). The highest root zone soil temperatures were recorded in the treatment with the greatest depth of snow cover, that being the tall stubble.

	FALL				WINTER			
TREATMENT	5cm	10cm	25cm	50cm	5cm	10cm	25cm	50cm
Mowed stubble	0.5	0.0	1.5	1.5	1.5	2.0	4.5	4.5
Tall stubble	0.0	0.5	0.0	1.5	1.5	2.0	5.0	5.0
Cultivated	0.5	0.0	0.0	1.0	1.0	2.0	1.5	5.0

Table 3. Soil temperature (°C) at depth according to treatment

CONCLUSION

It is apparent that standing stubble has the ability to trap snow and that the volume of snow trapped increases with an increase in stubble height. In addition, soil temperature was greatest under tall stubble as was the fall to winter increase in root zone soil moisture. Continued observations and data collection at this demonstration site will provide information into optimum stubble heights required to maximize snow trapped and also into relationships between snow depth, soil temperature and soil moisture content.

Further benefits which can be realized from proper stubble management include soil moisture conservation from reduced surface evaporation, erosion control, increased soil organic matter content and reduced plant winterkill due to the improved insulation potential from trapped snow.

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LONG-TERM SOIL MOISTURE TRENDS IN ALBERTA

A. Howard, J. Michielsen[1], J. Bell[2], and R.T. Heywood[3]

INTRODUCTION

Soil moisture maps have been developed annually by Alberta Agriculture for stubble fields in the fall since 1982 and for spring since 1988. During the drought conditions of the late 1980's and early 1990's, several questions were raised by agencies using the maps about "normal" soil moisture levels. With the type of database available, (ie maps with polygon units of soil moisture) a Graphics Information System (G.I.S.) appeared to provide the most reasonable approach to assessing long-term trends in soil moisture and identifying areas that are "usually wet" and areas that are "usually dry". In 1991, the Conservation & Development Branch undertook a G.I.S. analysis of the soil moisture maps to identify frequencies of various soil moisture levels in the fall and in the spring. This report presents the first results of the analysis.

METHODOLOGY

The software used for the analysis was GEOSQL for the graphics analysis and R-Base for database storage and analysis. The analysis required that the map polygons be converted to a raster format for storage in the database, and the unit chosen was a township. The map polygons were overlayed on a township grid and each township was assigned a soil moisture level for every map. In the cases where a township contained a boundary between two soil moisture levels, the soil moisture level assigned was that level which was most representative of the township. The result was that the database contained a soil moisture level (Very Low, Low, Medium, or High) for each township within the Agricultural Zone of Alberta for every fall from 1982-1992 (11 years) and every spring from 1988-1992 (5 years). Frequencies were then calculated and the results stored as fields in the database. Queries were then made to the database to identify the frequency of chosen soil moisture conditions during spring and fall. The conditions identified were extremely dry, dry, and adequate soil moisture. Extremely dry conditions were defined as soil moisture levels in the Very Low category. Dry conditions and adequate conditions were defined as soil moisture levels in the Very Low or Low category, and the Medium or High categories respectively. The frequencies chosen were 0-2 years, 3-4 years, 5-7 years, and 8 or more years out of 11 years for the fall and 0 years, 1-2 years, 3-4 years, and 5 years out of 5 years for the spring. The response to the queries was presented in a map format. The analysis has been completed for the dry conditions (Low and Very Low) in the fall. It is ongoing for the extremely dry and adequate fall moisture conditions and for all of the spring conditions.

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RESULTS

The fall map (Figure 1) shows that since 1982, southeastern Alberta, parts of south central and east central Alberta and the central Peace River region are dry at least 75% of the years. Almost all of southern Alberta, the eastern half of the province and most of the Peace River region are dry at least 45% of the years. Only the Whitecourt-Swan Hills area, west central Alberta, and parts of the northern Peace River region have had a low frequency of dry falls. A line extending from Calgary northeast through Castor, toward Wainwright separates a high-frequency area for dry falls to the southeast from a moderate (45-75%) to the northwest. This line roughly parallels the northern edge Dark Brown soil zone, but is approximately four townships south. Near Wainwright, the line moves sharply north, and includes the area around Vermilion. A northern extension of this high frequency zone includes the Two Hills, St. Paul and Vilna areas, which have been severely affected by drought since 1990.

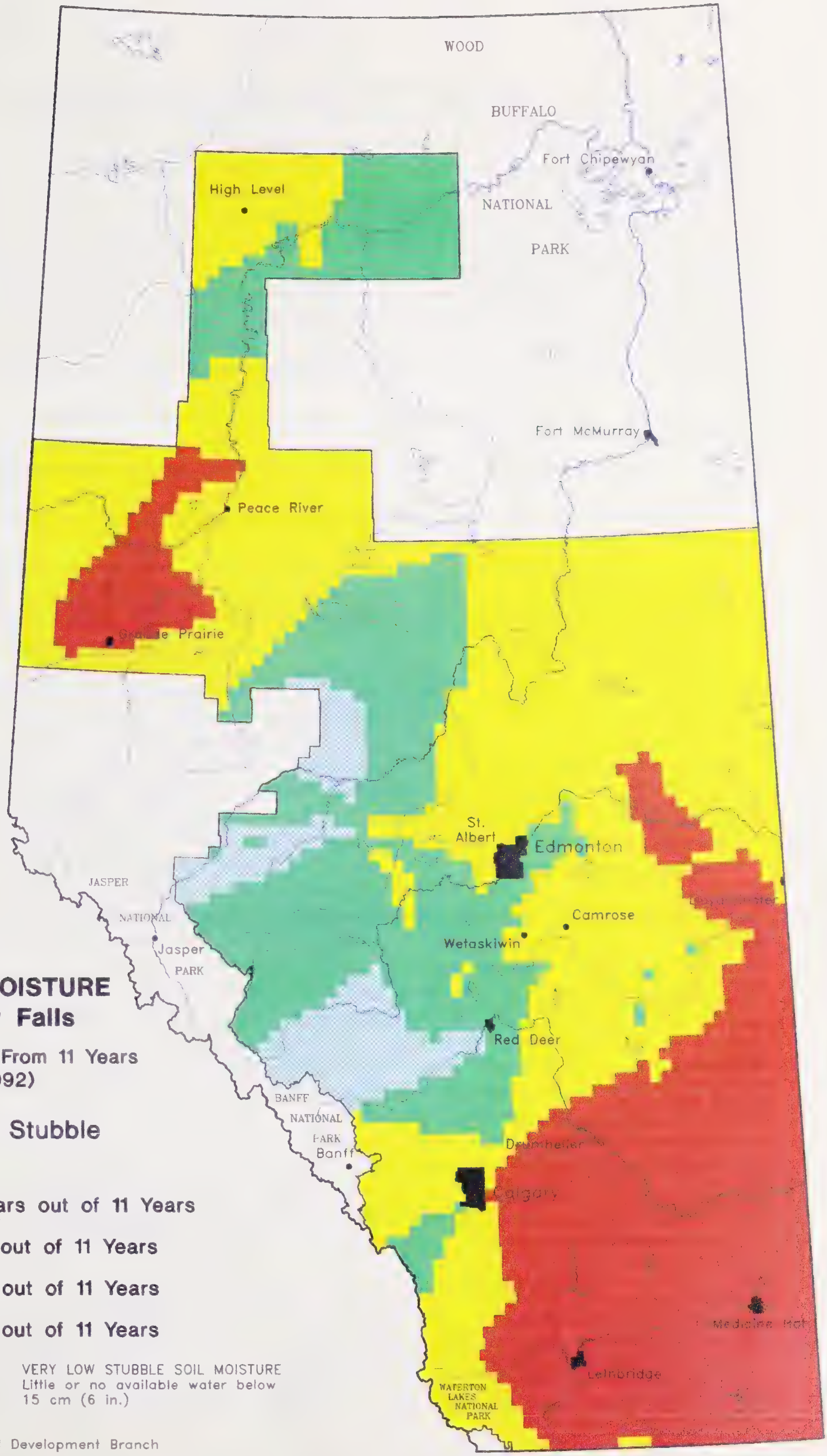
Preliminary results from the analysis of the spring maps (data not shown) show that dry spring soil conditions were found more than 60% of the time in much of eastern half of Alberta, but generally improve to adequate moisture levels in most of the southwestern, central and northwestern Alberta. Because of the shorter data record, individual spring storms resulted in a change in the frequency pattern of the spring maps that was not as evident in the analysis of the fall maps. As the analysis continues and the data record lengthens, the effect of individual storms will have less impact.

CONCLUSIONS

Dry fall conditions can be expected in southern, eastern and northwestern Alberta most of the time. The areas which had a frequency of dry fall conditions more than 75% of the time experienced problems associated with drought during the 11 year period of analysis. Based on the preliminary results from the spring map analysis, overwinter precipitation is expected to produce improvements from inadequate to adequate soil moisture reserves for annual cropping in most areas west of the fifth meridian, but in few areas east of the fifth meridian. As further analysis continues, specific regions subject to frequent dry or extremely dry soils will be identified. Identification of these areas will help focus water and soil moisture management extension activities, and help in establishing risk factors. In any area subject to frequent dry falls, use of specialized practices to conserve snow and soil moisture will be essential to the success of crop and livestock production if the current climatic trend persists.

ACKNOWLEDGEMENT

Appreciation is extended to Peter Dzikowski, Agricultural Weather Resource Specialist, C & D Branch of Alberta Agriculture, Edmonton for his ideas and input into the design of this project.



Alberta
AGRICULTURE

STUBBLE SOIL MOISTURE
Frequency of Dry Falls

Analysis of Information From 11 Years of Fall Data (1982 - 1992)

Low or Very Low Stubble Soil Moisture:

- 8 or More Years out of 11 Years
- 5 to 7 Years out of 11 Years
- 3 to 4 Years out of 11 Years
- 0 to 2 Years out of 11 Years

LOW STUBBLE SOIL MOISTURE
Subsoil moist to about 45 cm (18 in.)

VERY LOW STUBBLE SOIL MOISTURE
Little or no available water below 15 cm (6 in.)

Compiled by Conservation and Development Branch

ON-FARM WATER MANAGEMENT FOR ROTATIONAL GRAZING

S. Ali[1] , K. Williamson[2]

INTRODUCTION

This project was undertaken in 1991 to demonstrate the following:

(A) Water consolidation in rolling topography to provide and maintain a secure, good quality water supply for a rotational grazing pasture system.

(B) A grazing management system incorporating:

- (a) rotational grazing with flexible field sizes
- (b) pasture rejuvenation using rest and fertilizers and
- (c) extended grazing season strategies for perennial forage crops.

(C) An effective, economical insect pest management system.

Monitoring and data collection on this demonstration project began in 1992. The grazing management system and pest management components are covered in detail in a separate report by George Rock et al. The water management component of this demonstration compares free access and solar pumped watering system for pasture dugouts and how water quality for livestock is affected by these management practices.

METHODS

This demonstration project is located 8 km west of Camrose, Alberta, on SE 35-46-21-W4. Mr. Robert (Bob) Prestage is the cooperator.

Water Supply System:
On this rolling 64 hectares pasture, several wet depressional areas and potholes were drained to two dugouts. The size of the dugouts were based upon a two years water supply in drought years. A weather station to collect data on daily precipitation, temperature, relative humidity and snowmelt runoff yield was installed on June 17, 1992 on the main (west) dugout. The weather station consisted of a datalogger connected to a tipping bucket rain gage, water pump and temperature/relative humidity sensor. The data was collected from June 17 to September 30, 1992. Mr. Prestage fenced both dugouts so that the cattle would not have direct access to dugout water and installed a solar powered pumping system to supply water to cattle.

Water Quality:
Since the demonstration's dugouts never had cattle drinking directly from them, it was an excellent site for a comparison of water quality with a pasture dugout with direct cattle access. A direct access dugout in a neighbouring

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pasture, owned by Weyga Farms, was a similar size to the Prestage dugout. The Weyga dugout was three years old and supplied water to a herd of 200 head. The Prestage dugout was two years old and supplied water to a herd of 62 head. The watershed area for the Prestage dugout is entirely under forages. The watershed area for the Weyga dugout is a primarily pasture land with a small portion in cereal crop production. Cattle were turned out to the Prestage pasture on May 16, 1992 and were rotationally grazed on six pastures during the season.

Water samples were taken from both dugouts at a point about three metres out into the dugout and about 0.3 m below the water surface, on the first Wednesday of every month. Only one sampling point was used at each dugout for all samples.

Samples were placed in a cooler and transported to the Alberta Environmental Centre Laboratories in Vegreville for three tests:

(a) Routine chemical analysis
(b) Nutrient analysis
(c) Bacterial analysis

RESULTS AND OBSERVATIONS

Water Supply System:

1. To start with, both dugouts on Prestage and Weyga pastures were full of water from the 1992 spring runoff. The available water supply exceeded the demand from livestock.

2. Total precipitation on Prestage site was 130.0 mm from June 17 to September 30, 1992 which was well below the average of 269 mm (30 years record, Environment Canada, Camrose). The precipitation in the months of April and May was average but June and July precipitation was well below average.

3. Frost was recorded during the nights of May 20-21, 1992. Six days in mid August had maximum temperatures greater than 30° C. This was followed by five nights of frost on August 22-25, 1992.

4. The total drawdowns during the season on Prestage and Weyga dugouts were approximately 1.22 metres and 1.83 metres respectively.

5. Water consumption by cattle on the pasture is generally influenced by factors such as body size, type of feed, salt, dry matter intake and physical activity, in addition to air temperature and relative humidity. An analysis using Stepwise Linear Regression was carried out to find the correlation between daily maximum and average air temperatures and daily maximum and average relative humidities to daily water consumption by the cattle from June 17 to September 9, 1992 at Prestage Project. The daily average relative humidity was the most significant factor accounting for 34% of the variation in daily water consumption by cattle. When the maximum temperature factor was brought into the analysis, it increased the correlation by three percent.

   The analysis of data for individual months showed different percentage numbers of variation in daily water consumption. For the month of July, the daily average relative humidity alone explained 35% of the variation in daily water consumption, but the combination of daily average relative humidity and average temperature explained 49% of the variation in daily water consumption by the cattle. For the month of August, again the daily

average relative humidity was found the single most significant factor accounting for 55% of the variation in daily water consumption by cattle.

6. The daily average water consumption by cattle on Prestage pasture was determined to be 46 litres (10 Imp. gallons) per Animal Unit which seems reasonable considering the mixed sizes of the cattle grazing the pasture.

Water Quality:

Both dugouts were observed over the summer. As would be expected the Weyga dugout showed signs of damage by the cattle. The edges and ends were trampled and mud worked down the slopes by the cattle as they drank water. The water stayed relatively clear but had a slight muddy colour to it with just a hint of green. Rooted aquatic plants never became established because the cows trampled them while drinking. Since the water level went down all summer the weeds could not grow much before being above the water-line. The dugout was never treated with any chemicals but never showed any signs of an algal bloom. There was usually a small but insignificant accumulation of algae in the shallow water along the ends.

The Prestage dugout was an interesting comparison. Since the cattle were fenced out it remained undamaged. The water remained very clear, as shown by the Secchi depth readings. Some of these readings may have been deeper but the Secchi disc would hit bottom and limit the reading. A ring of water weeds grew along the edges and "billowing clouds" of algae grew along with weeds on the edges. This algae also invaded the stock tank that was used by the cattle. In September a small bloom of blue-green algae appeared on the leeward end of the dugout. There were some "grass clipping" algae (Aphanizomenon fos-aquae) in the water at this end and a small amount of blue-green scum on the edge. The water in the rest of the dugout was still very clear.

The routine chemical analysis did not reveal significant changes over the summer. The total dissolved solids increased in both dugouts over the season, mostly due to evaporation of the water leaving a more concentrated solution in the dugout.

The higher iron levels in the Weyga dugout, in the earlier part of the summer, suggest that there may have been a shortage of dissolved oxygen in the water. The reducing conditions that result allow minerals such as iron, phosphorus and other trace elements to be dissolved from the bottom sediments.

Since phosphorus (P) is considered a major problem nutrient in water bodies, it was monitored in this project. As a general guideline phosphorus levels in the 0.025 to 0.050 mg/L range are adequate to start a blue-green algae bloom. Many dugouts with algae problems will contain "P" levels of 0.150 to 0.600 mg/L. Phosphorus readings in the Weyga dugout were as high as 0.860 mg/L, but no major algae bloom occurred. The "P" levels actually went down as the summer progressed. This is the opposite of what was observed in dugouts that were used in the University of Alberta dugout liming study. One possibility is that the phosphorus was being taken up by the growth of zooplankton and they were in turn grazing on the algae as the algae developed. The phosphorus decline was also unexpected because the cows that were drinking directly out of the dugout would have been contributing more manure to the dugout all summer. When you consider that a cow will eliminate about 50 grams of phosphorus per day, there should be more phosphorus in the dugout at the end of the season.

The amount of phosphorus in the water declined in conjunction with the iron level. This would suggest that the iron and phosphorus were precipitating as an iron-phosphorus complex. The phosphorus did not appear to be taken up in the production of plant matter in the Weyga dugout during the 1992 season.

The phosphorus levels in the Prestage dugout started at a season high of 0.113 mg/L and declined to 0.031 mg/L. The edge of the dugout was surrounded by water weeds with "billowing clouds" of what appeared to be filamentous algae. The phosphorus is assumed to have been taken up by the plants in the dugout.

Other nutrient levels, such as ammonia and total Kjeldahl nitrogen, were higher in the Weyga dugout than the Prestage dugout. Natural surface waters typically contain less than 0.1 mg/L ammonia. Higher levels are usually the result of decomposing organic matter. Ammonia levels in the Weyga dugout were recorded as high as 1.87 mg/L.

Bacteria Tests:

As would be expected the levels of fecal coliform and fecal streptococci were always significantly higher in the Weyga dugout than they were in the Prestage dugout.

The heterotrophic plate counts in the Weyga dugout were also higher than in the Prestage dugout, but not significantly higher.

GENERAL COMMENTS

The high nitrogen levels in the Weyga dugout were one probable reason that nitrogen fixing blue-green algae did not become established. However, there is still a high potential for the growth of non-nitrogen fixing types, such as Microcystis to form toxic blooms. The high levels of nitrogen, phosphorus and dissolved organic carbon can encourage the growth of pathogenic bacteria and are, therefore, not desirable in any water supply.

The low levels of silica in the Prestage dugout also suggest a healthy benthic layer of diatoms; this "biological barrier" can be effective in preventing the release of phosphorus from the sediments.

Maintaining the low levels of phosphorus in the Prestage dugout will ensure that the threat of algal toxin formation will be small.

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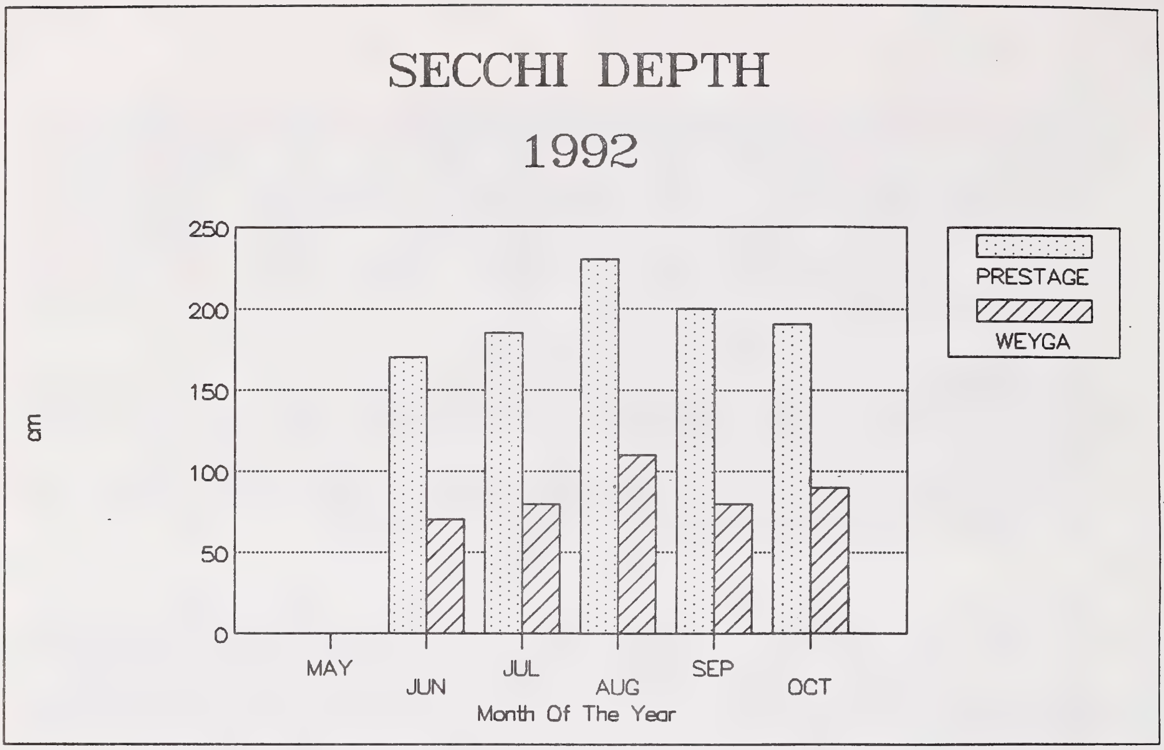
SECCHI DEPTH
1992
250
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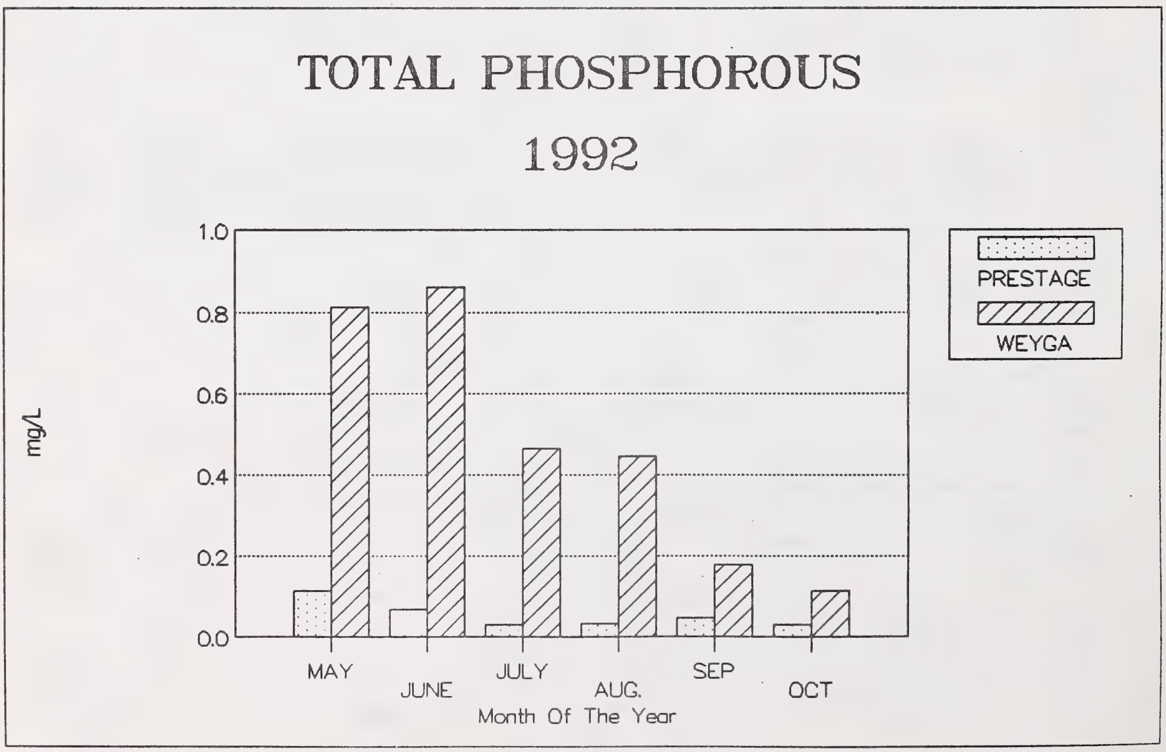
TOTAL PHOSPHOROUS
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EVALUATION OF SPRING BACKFLOOD IRRIGATION IN CENTRAL ALBERTA

J. Prochnau, N. MacAlpine, S. Ali[1] and E. Bittner[2]

INTRODUCTION

Spring backflood irrigation uses snowmelt to recharge root zone soil profiles with moisture before the growing season begins. In Canada's southern prairies, spring backflood irrigation has been used for many years. However, in central and northern Alberta, snowmelt is generally regarded as excess water and a nuisance to get rid of as quickly as possible.

Forage and cereal crops often suffer from drought stress later in the summer when moisture in the root zone is used up. Also, the pressure to move large volumes of snowmelt water off the farm can result in high capital costs to upgrade off-farm drainage systems.

Both factors justified a well documented demonstration of the on-farm benefits of managing spring snowmelt to recharge root zone soil moistures and the off-farm benefits of reduced peak flowrates and flood protection. The Golden Glow Spring Backflood Irrigation Demonstration was initiated by the County of Leduc and Alberta Agriculture in 1989. Monitoring was completed in 1992. Activities and results over the demonstration's lifetime are summarized.

SITE DESCRIPTION

The Golden Glow Spring Backflood Irrigation Demonstration in the County of Leduc near Millet is a combination of spring backflood irrigation and controlled drainage on what was previously a seasonal wetland. The project's 810 hectares of contributing watershed area delivers approximately 94,850 cubic metres of runoff water into the backflood lowland of 22 hectares. In July 1989, the 500 metre long outlet channel was reconstructed. A ditch berm was built in the channel to accommodate the stop log control structure on a 400 mm diameter corrugated metal pipe. Erosion-control blocks (MiniSLAB) were also installed over the control structure's berm to provide a farm crossing and erosion protection from overflow.

Two sites were selected in 1990 to compare the performance of forage varieties under dryland (upland) and backflood conditions. The upland site was on sandy loam soils, west of the backflood area and the backflood site was on a deep well decomposed peat soil. The forages evaluated were two legumes (alfalfa and alsike clover) and four grasses (Climax timothy, Carlton bromegrass, creeping foxtail and reed canary grass). Each variety plot was replicated three times per site plot. Plot yields and forage quality were measured in 1991 and 1992. New varieties were seeded in 1992 for future monitoring. The new varieties were seeded into the 1990 plots and replicated two or three times in both the backflood and upland plots. The new forage varieties were tall fescue, tall wheatgrass, western wheatgrass, Climax timothy and Magna bromegrass.

A weather station was set up at the site on June 1, 1990. It consisted of

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a manual Type B rain gauge, a tipping bucket rain gauge and a Stevenson Screen which housed a temperature and relative humidity sensor and a Campbell Scientific CR10 datalogger.

METHOD

The climate station was equipped for automatic recording of daily maximum and minimum temperatures, relative humidity, and rainfall including intensity and duration. Thermocouples were installed to manually monitor soil temperatures and frost recession. Four thermocouple nests were placed in each of the upland and backflood plots. Each nest had a thermocouple at depths of 5, 10, 20, 40, 60, 80, and 100 cm. Frost recession was measured by probing down to the frost layer using a Brown Probe. Runoff measurements, primarily at snowmelt, required frequent visits to record flood levels, flood duration, soil temperatures, and frost recession. Detailed mapping of the backflood area used to determine the volume of runoff and for comparison with regional data. The downstream drainage channel was surveyed for modelling the flood routing of snowmelt. Soil moisture levels were recorded by taking soil samples and also with a neutron probe. During spring runoff, observations and photos were taken of wild waterfowl staging on the backflooded area. Downstream flowrates and impacts were visually monitored, and high water marks were noted prior to construction in 1989 and after construction from 1990 to 1992.

Ackroyd et al (1993) completed a detailed farm financial analysis and socio-economic analysis. The farm financial analysis looked only at on-farm costs and benefits while the socio-economic (public) analysis also included off-farm development costs and associated benefits.

The backflood area was successfully cropped in 1992 with a canola crop underseeded to a mixture of bromegrass, meadow foxtail and timothy.

RESULTS

While only four years of data were collected, runoff monitoring at Golden Glow has vividly shown that snow damming in the outlet water course draining from the backflood area is a major hazard for downstream acreage owners. The most dramatic benefit from the demonstration has been the reduced flood risk for the two acreage homes downstream of a 1.8 metre diameter culvert. Before the demonstration's control structure was installed, the 1.8 metre culvert ran full in 1989 when a snowdam upstream broke loose. Both houses, only metres from the outlet watercourse as it flattens out and winds between the houses, were nearly flooded in 1989. With the demonstration's control structure operating, there were dramatically different effects downstream. It took 3 days for the 22 hectares of backflooding to drain dry in 1991 and 1992 compared to 5 hours in 1989 when there was no control structure. Backflood irrigation significantly improves downstream protection by controlling outflows when compared to the pre-construction natural conditions.

Based on only two years of forage sampling, the flood-tolerant forages of creeping foxtail and reed canary grass have performed best in the backflood plots. Alfalfa, alsike clover and bromegrass were the best forages for the upland area. In April 1991, a long duration backflood of 23 days tested the tolerance of backflood forages. Later on in the growing season, forages that had germinated poorly the previous year had strong competition from native grasses and sedges. The native grasses germinated from the seed bank in the soil built up before development began. Only strongly germinating tame forages like reed canary grass and creeping foxtail were able to out-compete the native species.

The economic analysis by Ackroyd et al (1993) proved that the project was financially viable from the on-farm perspective except for the scenario where field forage yields were assumed to be 20% lower than the yields from the backflood forage plots. The socio-economic analysis included the on-farm benefits and costs plus the downstream costs avoided by the County of Leduc and the downstream acreage owners by having the snowmelt runoff controlled by the project. As Table 1 illustrates, downstream protection provided a sizable benefit. The scenarios with forage yields increased or decreased 20% show that Benefit/Cost ratios are very sensitive to the forage productivity.

Table 1. Benefit/Cost Analysis

Socio-Economic B/C Ratios

Yield Rates	Farm Financial B/C Ratios	Option 1 Avoid Paying For Flooding Damages	Option 2 Avoid Upgrading Downstream Channels
Base Case: 7.8 tonnes/hectare	1.6	3.1	3.3
Yield Reduced by 20 %	0.9	2.3	2.5
Yield Increased by 20%	2.1	3.9	4.1

A 23 day long backflood in 1991, tested the effect of backflooding on soil thawing and temperature. Moist soils in the fall of 1990 plus a period of intense cold sent the frost deep resulting in a thick frost layer. The organic (peat) soils in the backflood area were very slow to thaw to a depth of 0.9 metres (3 feet). This is not typical of the infiltration observed on other spring backflood irrigation projects. However with drier soils in the fall of 1991 and an early spring in 1992, the peat soils thawed faster initially and then at the same rate as the upland soils in 1992. This is a preliminary indication that backflooding can speed frost removal but further monitoring is required. A summary of the frost recession is shown in Figure 1.

Thermocouple readings of soil temperature were taken during the spring runoff in 1991 and 1992. The readings indicated that the frost receded quicker from the upland plots in 1991. When the water was released the frost had receded to approximately 30 cm (12 inches) in the backflood plots compared to 90 cm (36 inches) in the upland plots. In 1992 the readings indicated the opposite in that the frost receded quicker from the lowland plots.

Soil tests were done on the project each year and there was an increase in electrical conductivity since 1989. In 1992, there was a dramatic increase in sulphur levels compared to 1991. Sodium levels were also very high. Soil testing will continue in future years.

Since wildlife monitoring was not conducted before the demonstration was initiated, the impact of shorter flooding and more intense agricultural use of the backflood area cannot be quantified. However, qualitatively, wildlife habitat value has been lost. The backflood area has been changed from a temporary wetland to a forage field. On the other hand, the spring backflooding continues to provide an important spring staging area for migrating waterfowl.

Figure 1. Forage Plots Frost Recession

SUMMARY AND CONCLUSIONS

Controlled drainage, as part of spring backflood irrigation, reduced peak flowrates below the pre-construction natural conditions. Downstream flooding at the acreages in 1989 under pre-construction conditions contrasted strongly with the controlled flowrates in 1990 to 1992. The 1989 snowmelt on this demonstration had an extremely erosive runoff rate (1:100 year peak flowrate) for a very average accumulation of spring snowmelt (1:2 year snowmelt volume). The demonstration changed the runoff situation from a sudden flood due to failure of snowdams in the outlet watercourse to a controlled and extended runoff event.

The project is financially viable under all scenarios except one. There was no agricultural use of this project's 22 hectares before development. Therefore the benefit/cost projections of this project should not be used on land that already has some level of agricultural production. However, without this demonstration, downstream acreage owners and the County of Leduc would have faced major construction costs to contain the natural uncontrolled flows as the snowmelt drought of the 1980's ended and snowmelt runoff conditions returned to normal.

The benefits from this project are dependent on the forage yields achieved. In the economic analysis of this project the sensitivity analysis used yields of plus or minus 20% of the base case forage yield of 7.8 tonnes/hectare, clearly showing the forage's real productivity under backflood is critical to the

project's financial viability.

Soil moisture levels in the fall determine the need for spring backflood irrigation. The contrast in soil thawing in 1991 and 1992 under spring backflood suggest that high soil moistures in the fall may form substantial frost layers that are slow to thaw even under flooding. Drier soils the previous fall may permit better infiltration of flooded water and consequently faster thawing. Regulated spring backflooding should be limited to years when the soil moisture was low the previous fall.

Although the more complete drainage required for tame forage production has reduced this area's wildlife habitat value, it still serves as an important spring staging area for migrating waterfowl. In spring, it is one of the first water bodies with extensive open water in the County of Leduc.

Further investigation of high value forages that tolerate spring flooding is needed. The best yielding forages under spring backflood irrigation were creeping foxtail and reed canary grass. Both yield well but have a short harvesting window for good quality. Consequently they usually provide lower quality forage than the typical upland forage. Other varieties that are competitive, tolerate flooding, and yield well are worth further investigation.

Weed control and selection of tame forages that germinate and compete strongly with the native wetland grasses and sedges is essential for tame forage establishment. Controlling the native grasses and sedges is very important. Spraying the native grasses with chemicals does not eliminate new growth of the native grasses and sedges from the seed bank. Good elimination of the native species at the time of establishment and good germination of the tame species is required to establish a competitive cover. Alternatively, the opportunity for equivalent yields and quality from native species is worth considering although the limited plot data from this project does not confirm that native species can yield as high as tame water tolerant species.

Based on the information gathered to date there needs to be well established forages before proceeding with backflood operations to accelerate spring soil thawing. New varieties of forage need to be tested and the Golden Glow project has the right conditions to monitor these issues.

Copies of the Golden Glow Spring Backflood Demonstrations Annual Reports, Final Report and Economic Analysis and Hydrologic Modelling Report can be obtained by contacting the Conservation and Development Branch in Edmonton.

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AUTOMATED MONITORING OF SALINITY LEVELS IN WATER ENTERING VERDIGRIS LAKE

Murray Riddell[1] and Dennis Mikalson[2]

INTRODUCTION

Accurate estimates of the amount of salt entering Verdigris Lake from the inlet canal are essential for calculating salt balances for the reservoir. Previous sampling of the inlet canal had shown electrical conductivity (EC) levels to increase from background levels of around 0.3 mS cm^{-1} up to levels between 1 and 4 mS cm^{-1} during and after rainfall events. The magnitude of these EC increases and duration for which peak EC levels were maintained during such events were not well quantified.

In response to this need to further quantify salt loading into the reservoir, a salinity monitoring station was installed at an existing flow monitoring station on the inlet canal to Verdigris Lake.

METHODS

The automated salinity monitoring station was installed along the inlet canal to Verdigris Lake, adjacent to a flow monitoring station operated by the Irrigation Branch of Alberta Agriculture (Figure 1) The salinity monitoring station consisted of a Model 228 Toroidal Conductivity Sensor installed in the canal water, a Model 1181T Two-Wire Toroidal Conductivity Transmitter to energize the sensor and output a linear signal and a CR-10 data logger to record information from the transmitter (Figure 2).

The transmitter and sensor were calibrated in the laboratory according to procedures provided by the manufacturer. In the field, output from the salinity sensor was checked and adjusted to EC values determined with portable conductivity meters. Water samples were taken at each field visit to check the accuracy of the portable conductivity meter. Instrument verification and downloading of data were performed weekly until the sensor stabilized and at monthly intervals thereafter.

The datalogger was programmed to take salinity readings at 20 minute intervals in order to check for variation during high intensity rainfall events. Electrical conductivity (dS m^{-1}) was converted to an equivalent Total Dissolved Solids (TDS) using an equation developed by Chang et al. (1983).

$$TDS\ (mg\ L^{-1}) = 765*EC^{1.087}$$

Total dissolved solids was then merged with flow monitoring data. Flow and TDS values between 20 minute intervals were multiplied to determine salt flux and were summed to compute daily salt loadings.

RESULTS

Salinity (EC) levels and salt flux of the water entering Verdigris Lake was

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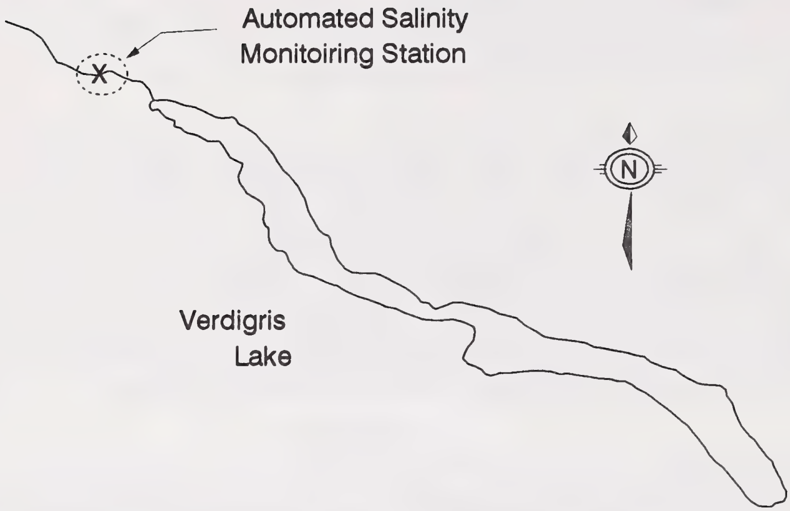

Figure 1. Location of automated salinity monitoring station
on inlet canal to Verdigris Lake.

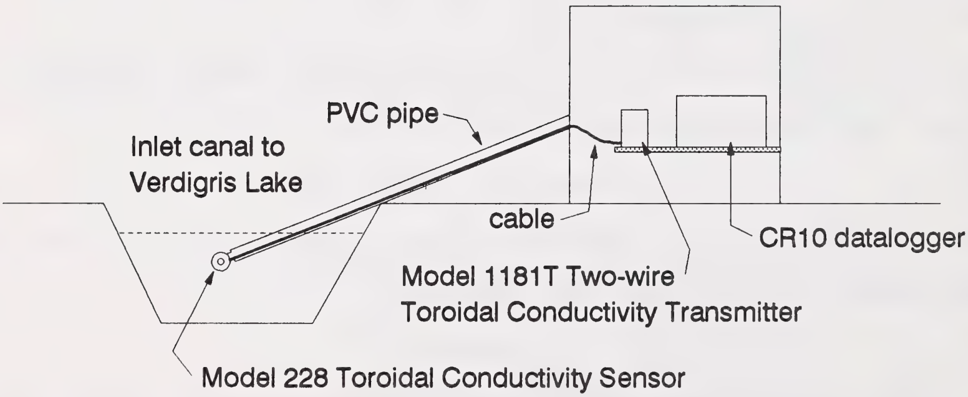

Figure 2. Instrument set up for automated salinity monitoring station.

shown to fluctuate dramatically in response to rainfall events (Figure 3). Two separate rainfall events in late June (approximately 50 mm) and early July (approximately 30 mm) caused salt flux levels in the canal to jump from background levels of 15 tonnes day^{-1} to levels between 120 and 170 tonnes day^{-1}. Background salt flux levels declined from approximately 15 tonnes day^{-1} to less than 10 tonnes day^{-1} over the monitoring period.

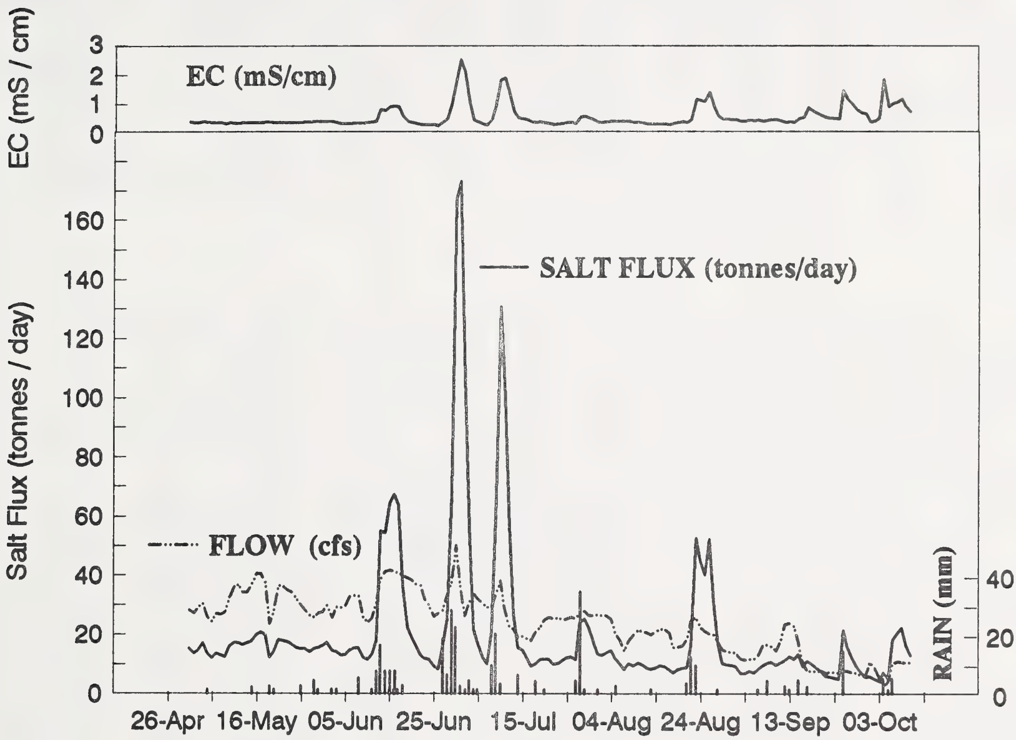

Figure 3. Fluctuations in salt flux (tonnes / day), salinity levels (mS / cm) and flow (cfs) in the inlet canal to Verdigris Lake in response to rainfall events.

Installation of the automated salinity sensor on the inlet canal to Verdigris Lake provided the continuous monitoring capability necessary to document salt fluxes during rainfall events and calculate the total amount of salt entering Verdigris Lake from the inlet canal. Field calibration and checking ensured the salinity monitoring station provided accurate and precise measurements.

Background salt fluxes in the inlet canal ranged from 10 to 15 tonnes day^{-1} during the monitoring period. Rainfall events of 10 mm or larger caused salt fluxes to increase above background levels. In general, the higher the intensity and the longer the duration of the rain event the greater the increase in salt flux.

NITRATE LEVELS IN SOIL AND GROUNDWATER BELOW IRRIGATED FIELDS RECEIVING MANURE APPLICATIONS IN SOUTHERN ALBERTA

K. M Riddell[1]

INTRODUCTION

The most common method for disposing of feedlot manure in the irrigated areas of southern Alberta is yearly spreading on adjacent crop land. This practice may cause agronomic and environmental problems if excessive levels of nitrogen and phosphorus accumulate in the soil. Groundwater can be contaminated if nitrates (NO_3-N) produced from manure are leached to the water table.

In response to this concern, Alberta Agriculture began to monitor NO_3-N levels in soils and groundwater beneath typical irrigated, manured and non-manured fields. The objective of this study was to provide information for planning future monitoring and research.

METHODS

Seven irrigated sites were studied during 1990 and 1991. A summary of soil landscape features, irrigation methods, crops grown and estimated fertilizer and manure application rates at each site is presented in Table 1.

Three to four soil/groundwater sampling locations were set up in a manured and non-manured field at each site (Figure 1). Sampling locations were put in lower and depressional slope positions in 1990 and in upper, mid and lower slope positions in 1991.

Soil sampling was done after seeding and harvest. Soil samples were taken by 0.15 m depth intervals to a depth of 0.6 m and by 0.3 m intervals thereafter. Hole depths were limited to 3 m because of shallow water tables in low areas in 1990. Hole depths ranged from 1.5 to 13.0 m because of variable depths to groundwater at different slope positions in 1991.

Soil samples were collected in insulated bags to prevent heating and were set out to air dry within two to six hours of sampling. Soil samples were analyzed for major ions, pH and electrical conductivity (EC) (Rhoades 1982). Nitrates were determined using a colorimetric method (Technicon Industrial Systems Corp. 1986).

Groundwater instrumentation was installed during spring soil sampling. One water-table well was installed at each sampling location in 1990. One water-table well and one or more piezometers were installed at each sampling location in 1991. Groundwater samples were collected every two weeks from May to November and were analyzed for major ions using the same methods as for soil samples.

RESULTS AND DISCUSSION

<u>Soil NO_3-N</u>

Average fall soil NO_3-N levels in the upper (0-0.6 m) and lower (0.6-1.2 m) root zones were much higher under manured as compared to control fields at all sites except L (Table 2). The range of variation in soil NO_3-N levels between the four sampling locations in each field was also much higher in manured as compared to control fields at all sites except L (Table 2).

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Table 1. Summary of landscape, geology and management features at each site.

Site	Treatment	Surface Expression/ Landform/Soil	Bedrock Depth (m)	Irrigation Method	Crop	Fertilizer Rate (kg/ha) and Method	Manure Application Rate & Method
B	Manured	undulating/glacio-fluvial-eolian/Orthic Brown Chernozemic	> 3	Pivot since 1980	Corn	8 N } 35.5 P } drilled with seed 15 K } 36 N through pivot in growing season	60 - 120 t/ha, alternate falls since 1981. Incorporated by discer following spreading.
	Recently Manured	undulating/glacio-fluvial-eolian/Orthic Brown Chernozemic	> 3	Wheel Roll	Canola	140 N } 45 P } broadcast in spring 11 S } and then cultivated	Fall of 1990: 1st application 85 t/ha incorporated during the next week using a moldboard plow
C	Manured	undulating/glacio-fluvial/Gleyed Brown Chernozemic	> 3	Pivot since 1975	Corn	last application was in 1987	17-20 annually since 1975, incorporated within 1 week of spreading
	Control	same as above	> 3	Wheel Move	Wheat	84 N broadcast & plowed in during April	————
D	Manured	rolling/glacio-fluvial over till or bedrock/ SITE R7: Gleyed Dark Brown Solods SITES R5 & R6: Orthic Brown Chernozemic	> 3 at R7 1.7 at R5 1.9 at R6	Wheel Roll	Barley	6 N - 27 P - 8 S - 8 K incorporated with seed in early July. 76 N broadcast in fall of 1990 (not incorporated)	Fall/90: 150 t/ha fresh manure spread & incorporated with cultivator Spring/90: 325 t/ha manure spread and not incorporated Manure application started in 1975 & was done approx. every 3 years prior to 1990.
	Control	rolling/glacio-fluvial on till/Gleyed or Orthic Dark Brown Solodized Solonetz	> 3	Wheel Roll	Grass with 20% Alfalfa since 1985	38 urea N broadcast in spring of 90 and 91	————
F	Manured	rolling/fine loamy fluvial or lacustrine/Orthic Dark Brown Sites 3 & 4: Chernozemic	> 3	Wheel Roll	Tame pasture (Triticale & annual rye grass) Spring 91	38.2 N broadcast then irrigated	1st time in 1990 spring 1990 & 1991: rates varied from 70 to 150 t/ha^{-1}
	Control	level/fine loamy fluvial or lacustrine/Orthic Dark Brown Chernozemic	> 3	Pivot Wheel Roll #C2	Alfalfa 1985 Tame Grass 1980-85	30.9 N 143.1 P broadcast then irrigated	————
L	Manured	undulating/till plain with pockets of veneer or blanket glacio-lacustrine overlying till/Calcareous Dark Brown Chernozemic	> 3	Wheel Move	Barley in early May	33 N banded in fall of 1989	50 during fall of 1987, incorporated within a week of spreading
	Control	same as above	> 3	Wheel Move	Soft Wheat	101 N broadcast in spring	————
M	Manured	undulating/glacio-fluvial & glacio-lacustrine deposits over till/saline Dark Brown Chernozemic	> 3	Wheel Move	Barley since 1987	90 N (Anhydrous Ammonia) banded in the spring & 67 P drilled with the seed	50 - 60 annually since 1987, in late August & disced within 1 week
	Control	same as above	> 3	Wheel Move	Barley since 1989	112 N banded in the spring of 1990 78 N banded in the spring of 1989	Management: locations 1 & 2: shallow plowed before seeding locations 3 & 4: deep plowed & irrigated before seeding
R	Manured	undulating and low hummocky. Veneer of coarse loamy, weakly calcareous fluvial material over till/Orthic Brown Chernozemic	> 3	Pivot	Potatoes	6 N - 22.5 P - 47 K broadcast in spring & cultivated under 11.5 N broadcast in July & cultivated under	Sites 1 & 2 - March/91: 155 t/ha fresh manure spread & cultivated Sites 3 & 4 - Oct/90: 105 t/ha fresh manure spread & cultivated - manured annually since 1970
	Control	undulating and low hummocky. Veneer of coarse loamy, weakly calcareous fluvial material over till/Orthic Brown Chernozemic	> 3	Flood	Canola	no fertilizer	————

	Manure Application Rate	Manure Application History	Total Fall NO_3-N Kg ha^{-1} Upper Root Zone (0-60 cm)				Total Fall NO_3-N Kg ha^{-1} Lower Root Zone (60-120 cm)			
			Control		Manured		Control		Manured	
			Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
SITE B (fall of 1990)	60-120 t ha^{-1}	Alternate falls since 1981	6	2-10	437	137-588	7	4-10	307	37-759
SITE C (fall of 1990)	17-20 t ha^{-1}	Annually since 1975	30	1-92	216	90-326	39	12-102	304	188-408
SITE D (fall of 1991)	150 t ha^{-1}	Every three years since 1975	0		64	7-102	0.4	0-1.1	87	62-136
SITE F (fall of 1991)	70-150 t ha^{-1}	Annually since 1990	0		8	0.2-18	5	0.5-11	17	1-37
SITE L (fall of 1990)	50 t ha^{-1}	Annually since 1987	220	22-514	126	25-242	224	17-481	54	11-101
SITE M (fall of 1990)	50-60 t ha^{-1}	Annually since 1987	21	4-37	52	1-178	62	18-96	99	2-193
SITE R (fall of 1991)	100-150 t ha^{-1}	Annually since 1970	25	0-91	96	1-291	29	0.5-56	194	0.4-459

Table 2. Manure application rates, manure application history and average values (n=4) for 1990 or 1991 total-fall NO_3 -N (kg ha^{-1}) found in the upper (0-60 cm) and lower (60-120 cm) root zone of control and manured fields at seven irrigated sites across southern Alberta.

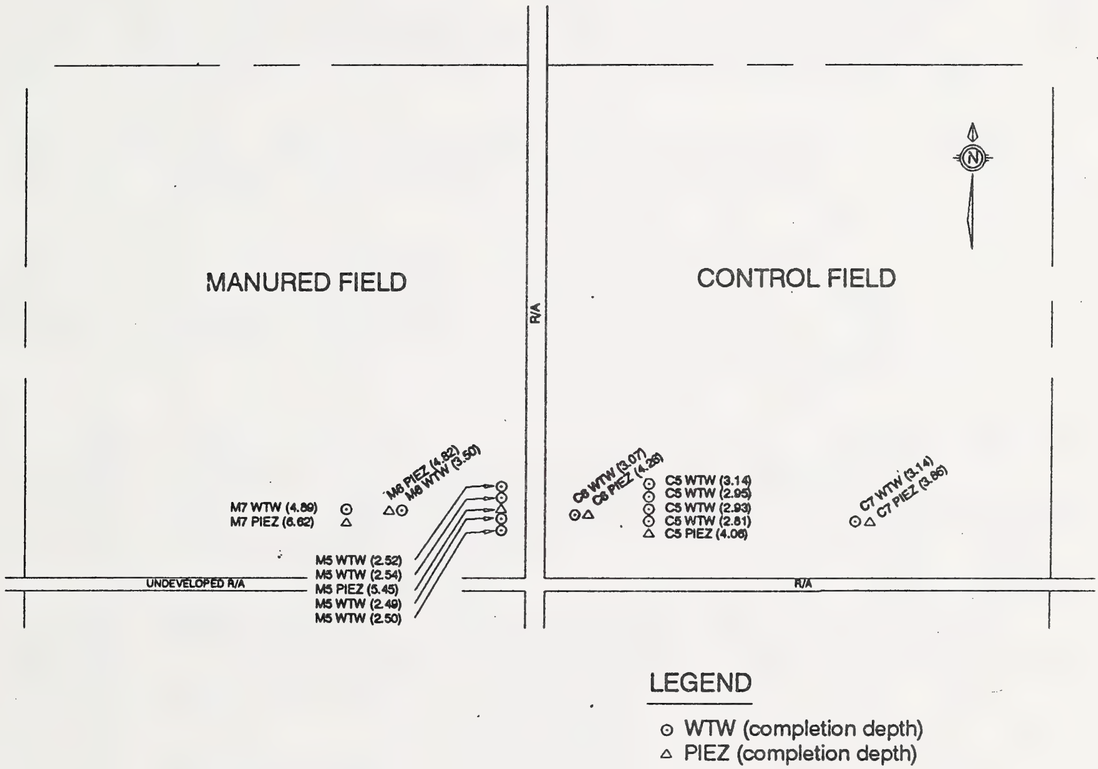

Figure 1. Location plan showing water-table well and piezometer locations on manured and control fields at Site D.

The highest fall soil NO_3-N levels (194-307 kg ha^{-1}) in the lower root zone were found under manured fields at Sites B, C, and R (Table 2). Manure has been applied yearly since the 1970's at Sites C and R and every second year since 1980 at Site B. The soil parent material at all three sites was sandy loam, fluvial-lacustrine. Manure application rates at these sites varied from 17 to 150 t ha^{-1} (Table 2).

Annual application of manure at rates of 60 t ha^{-1} for four years at sites L and M resulted in NO_3-N levels ranging from 54 to 99 kg ha^{-1} in the lower root zone. Large applications of manure (150 t ha^{-1}) every three years since 1975 resulted in NO_3-N levels of 87 kg ha^{-1} in the lower root zone at Site D. Two applications of manure in the springs of 1991 and 1992 at rates ranging from 70 to 150 t ha^{-1} resulted in NO_3-N levels of 17 kg ha^{-1} in the lower root zone at Site F.

Average soil NO_3-N levels in the lower root zone under the control fields were less than 60 kg ha^{-1} at six out of seven sites (Table 2). The average soil NO_3-N level in the lower root zone at Site L was 224 kg ha^{-1} (Table 2). The high soil NO_3-N at Site L may have been caused by excess nitrogen fertilizer application.

Comparison of 1990 to 1991 results shows higher NO_3-N in the root zone under manured and control fields in 1990 when soil sampling was done at lower slope positions (Table 2). Reasons for NO_3-N build up at lower slope positions include reduced crop uptake due to salinity and/or waterlogging and concentration by groundwater or surface water flow.

Groundwater NO_3-N

Higher average NO_3-N levels in groundwater were found under manured as compared to control fields at five out of seven sites (Figure 2). Average groundwater NO_3-N concentrations under manured fields at Sites B, C, D, F, and R ranged from 10 to 100 mg L^{-1} (Figure 2). Average groundwater NO_3-N concentrations under control fields at the same sites ranged from 0.1 to 10 mg L^{-1} (Figure 2).

The highest groundwater NO_3-N levels were found under manured fields at Sites B, D, and R (Figure 2). Groundwater NO_3-N levels at these three sites were consistently around 100 mg L^{-1} (Figure 2). Manure application rates were very high (100 to 150 t ha^{-1}) at all three sites. The soil parent material at all three sites was sandy loam, fluvial-lacustrine.

Higher groundwater NO_3-N levels were found under the control as compared to the manured field at Site L (Figure 2). The average groundwater NO_3-N level ranged from 50 to 100 mg L^{-1} under the control field and from 0.1 to 80 mg L^{-1} under the manured field at Site L (Figure 2).

CONCLUSIONS

Results show that repeated spreading of feedlot manure on the same land caused higher average NO_3-N levels in the soil root zone and shallow groundwater when compared to adjacent non-manured fields. The size of the increases in NO_3-N levels in the soil root zone and shallow groundwater under manured fields were extremely variable. The largest increases in average NO_3-N levels in the lower root zone were observed under fields with sandy loam soils and the longest history of manure spreading. The largest increases in average groundwater NO_3-N levels were seen under fields with sandy loam soils and the highest rates of manure application.

Soil NO_3-N levels of 200 to 300 kg ha^{-1} in the lower root zone and groundwater NO_3-N levels around 100 mg L^{-1} at three out of seven sites is

sufficient evidence to suggest further monitoring is warranted. More efforts should be made to educate producers about the agronomic and environmental costs associated with NO_3-N leaching under irrigated land receiving repeated applications of manure. Combined with monitoring, is the need to study the relative importance of manure application rates, geology and soil parent material, groundwater flow direction, denitrification, timing of manure application, irrigation management and post-application tillage practices in influencing NO_3-N levels under irrigated, manured fields.

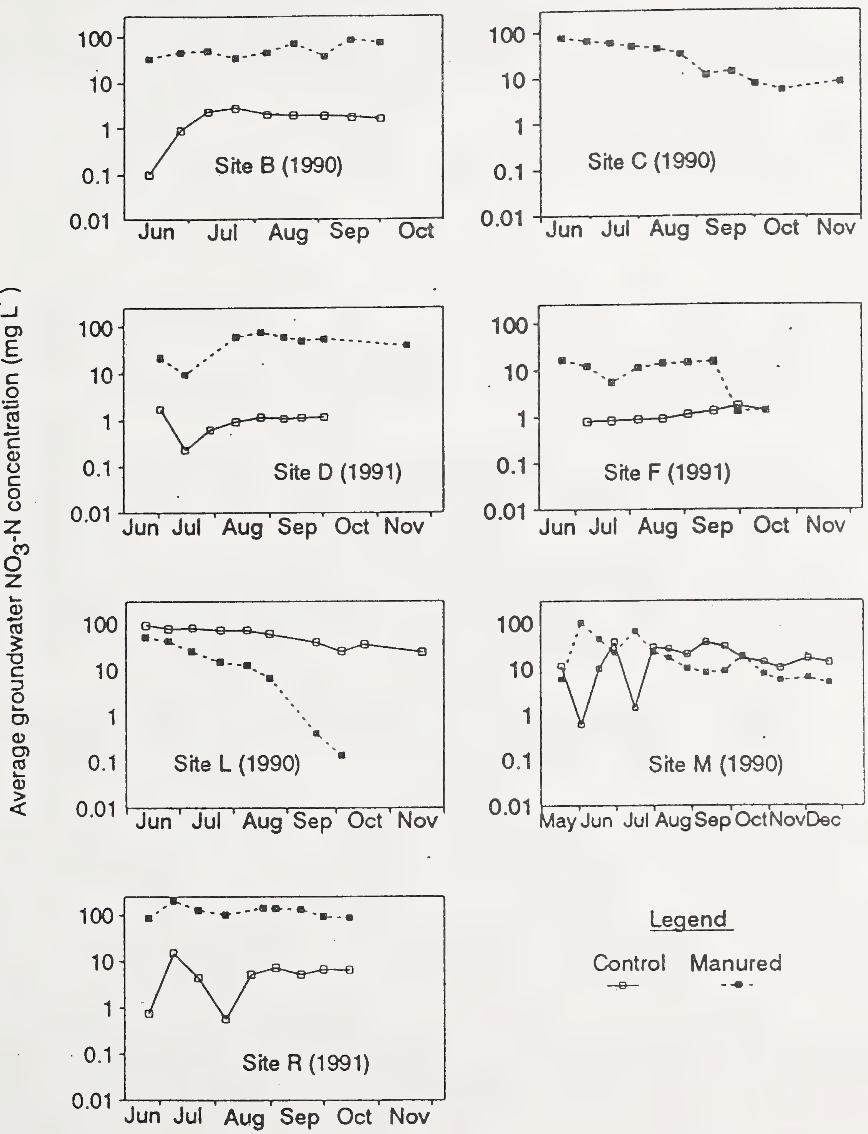

Figure 2. Average groundwater NO_3-N concentration from June to November under manured and control fields at seven irrigated sites across southern Alberta.

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MONITORING FOR PESTICIDES AND HERBICIDES IN SOUTHERN ALBERTA -1992

S. J. Rodvang[1]

INTRODUCTION

Drain effluent and shallow groundwater were monitored for the presence of herbicides at five subsurface drainage locations in southern Alberta during the summer of 1991. Herbicides were detected at three out of five locations, with the highest levels occurring when irrigation or rainfall occurred soon after herbicides were applied (Rodvang et. al. 1992).

Monitoring of drain effluent is a cost-effective way to obtain integrated samples under conditions which favour herbicide leaching to groundwater. Herbicide and pesticide monitoring in 1992 was conducted at two undrained study areas to determine the amount of herbicide leaching under conditions more representative of irrigated areas in southern Alberta. Drain effluent was also sampled at one site.

METHODS

Description of Study Area 1

The hydrogeology at Study Area 1 was characterized by Hendry (1981). The area consists of a north-south transect between two groundwater flow divides, with flow occurring mainly from a canal in the north to the Bow River in the south (Figure 1).

Surficial geology consists of about 15 to 45 m of weathered till, with abundant surficial and buried sand layers and lenses, overlain by 1.5 to 3 m of lacustrine material. The water table depth in the study area ranges from about one to five metres (m) with an average depth of 2.3 m.

Study Area 1 was developed for surface irrigation between 1920 and 1940. Wheel moves were introduced during the 1960's and 1970's, and centre pivots were introduced over much of the area during the 1980's. Growing season precipitation and evaporation average 22 cm and 75 cm, respectively. About 85 cm of water is delivered to the study area per year (Rapp and van Schaik 1972).

Land Use, Groundwater Installation and Sampling at Study Area 1

A telephone survey was conducted in the late summer of 1992 to determine which pesticides were applied to Study Area 1 in 1992.

Stainless-steel water-table wells and piezometers were installed at eight locations along the transect in August 1992 (Figure 1). The first five sites were located in grassed areas at the edges of cultivated fields. Sites 6 to 8 were located at the edges of non-native pasture. Sites 3 and 5 were located in isolated depressions. The water-table depth at sites 1 to 5 ranged from about 1.2 to 5 m, while at sites 6 and 7 the water-table was 5 to 7 m deep.

Organic samples were collected from Study Area 1 in early September of 1992.

Land Use, Groundwater Installation and Sampling at Study Area 2

Potatoes were irrigated with a pivot in both 1991 and 1992. Eptam (active ingredient EPTC) and Lexone (active ingredient metribuzin) were applied on April 24. The site was irrigated on April 26, and potatoes were seeded on April 27.

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Thimet (active ingredient phorate) was applied with the seed. Gramonone (active ingredient paraquat) was applied on May 27, and Furidan (active ingredient carbofuran) was applied on June 29.

Stainless-steel piezometers and water-table wells were installed at five locations in topographically low spots on the field. Site 6 was located at the edge of the quarter in non-native grass and weeds. Samples were collected following rainfall and irrigation events on five occasions between May 15 and July 2 (Figure 2).

Description of Study Area 2

Study Area 2 (Figure 1) was underlain by less than one to greater than five m fluvial-lacustrine material of sandy loam to silty-clay texture, over weathered till.

The water-table depth in the cultivated area ranged from a maximum of 3.8 m at site 2 during the dry period in early May, to a minimum of 0.5 m at Site 4 following rainfall and irrigation events in July. Water-table fluctuation between May and July ranged from 1.3 m in the lowest spots, to 0.2 m at Site 2. The water table at Site 6 rose from 5.2 m in mid-May to 4.6 m in July.

Description of Study Area 3

Study Area 3 (Figure 1) was a drainage outlet for a five-acre subsurface drainage site. The outlet flowed in response to irrigation and rainfall events, at a maximum flow rate of about 4 litres per second. Drain effluent quality monitoring in 1990 indicated that the electrical conductivity of the effluent ranged from 6.3 dS/m in May, to 1.1 dS/m in late August.

Land Use and Sampling at Study Area 3

Avadex (active ingredient Triallate) was applied on April 16, and the field was planted to barley in late April. Samples were collected following rainfall and irrigation events on May 12, May 16, May 20 and June 10.

Installation of Stainless-Steel Piezometers at Study Areas 1 and 2

Stainless-steel piezometers installed at Study Areas 1 and 2 were made from tubular lengths of stainless-steel, slotted at 4-cm intervals over the screened area. Stainless steel end-caps were welded on the bottoms, and screw-locking top caps were added after installation.

Piezometers were washed with acetone followed by de-ionized water, and wrapped tightly in brown paper for transport to the field. Solid-stem augers and drilling bits were pressure-washed with hot soapy water, followed by a rinse with acetone, and a final rinse with de-ionized water before drilling. Augers were then wrapped in large plastic bags for transport to the field.

The upper 15 cm of soil was removed before drilling at each site. Surface soil and drill cuttings were not allowed to fall into the drill holes during drilling. Piezometers were backfilled with washed silica sand around the screened intervals, followed by bentonite to the ground surface. One auger blank sample was collected from each study area, by running de-ionized water off the auger and into a sample bottle.

Screened intervals on water-table wells at Study Area 1 were generally 3 m long, with additional piezometers at some sites being 0.3 to 1.0 m long. Screened intervals on water-table wells at Study Area 2 ranged from 1.7 to 3.5 m long, while screened intervals on piezometers ranged from 0.5 to 0.8 m long.

Organic Sampling

Several well volumes were removed from each new stainless-steel piezometer

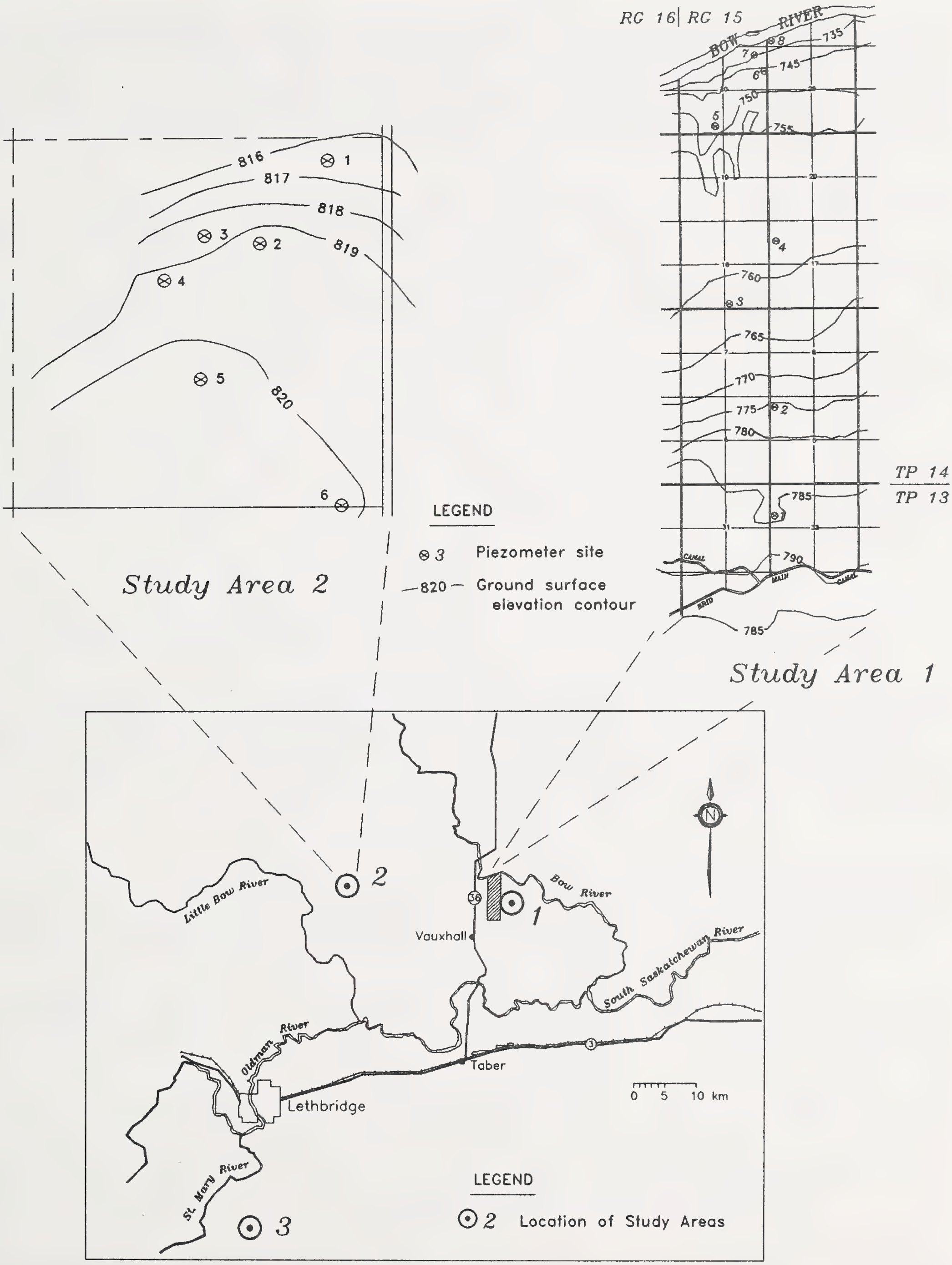

Figure 1. Location of Study Areas

before sampling. Samples were collected using dedicated stainless steel bailers which had been rinsed with acetone and de-ionized water. Samples were collected in one-litre glass tinted bottles, and transported to Lethbridge in coolers with ice. The next morning, water was decanted off and the sediment left in the bottom of the bottles was frozen at -40°C. Water samples were shipped in coolers with ice-paks to the analytical laboratory in Edmonton.

Organic Analysis

A total of 31 pesticides and herbicides were analyzed at Study Area 1. Analytical scans were selected based on cost, pesticides applied, and their predicted mobility and degradation rate.

The applied herbicide EPTC was not analyzed at Study Area 2 because accurate analytical methods for its determination have not been established (Bruns Personal Communication). The applied herbicide paraquat was not analyzed because it is quickly degraded and strongly bound, and therefore unlikely to be detected in groundwater.

Organic analyses were conducted using a gas chromatograph with a mass-selective detector. Blind spikes sent to the analytical laboratory indicated that the method was highly accurate with respect to pesticide identification, with an approximately -+ 50% accuracy with respect to concentration (Hill Personal communication).

RESULTS

Herbicides were not present in auger blanks. No pesticides or herbicides were detected in samples collected from Study Area 1.

Three samples at Study Area 2 contained detectable herbicides. A trace of phorate was detected in water-table-well #1 on May 12. Water-table-well #6 contained 0.12 ppb metribuzin on June 13, and 0.086 ppb metribuzin on July 2.

Triallate was not detected in drain effluent at Study Area 3, with the exception of 1.1 ppb on May 20.

DISCUSSION

Study Area 1

Samples were not collected from Study Area 1 until about five months after most of them were applied. The long interval between application and sampling, in addition to the dry spring, would allow ample time for pesticides to be sorbed, degraded, or dispersed by groundwater flow. However, the lack of detection of a very wide scan of pesticides applied in Study Area 1 suggests that groundwater in this area may be relatively free of contamination, at least some of the time.

Study Area 2

Pesticide Mobility: For each organic chemical, the distribution coefficient normalized to the amount of organic carbon in the soil, or Koc, measures the amount of that chemical which will be sorbed to a given soil, relative to the amount in solution.

Koc values were calculated using the method of Karickhoff (1981). For the pesticides detected at Study Areas 2 and 3, phorate and triallate have relatively high Koc values (4.05 and 4.66, respectively), indicating that they are relatively immobile in water. The detected pesticides metribuzin and carbofuran, ith Koc values of 1.32 and 1.28, respectively, indicate that they are relatively

mobile in water.

A trace of phorate was detected during the first sampling event on May 12, even though Koc values predict a greater mobility for metribuzin. Metribuzin was detected following recharge events on two later occasions. Carbofuran, an apparently mobile pesticide, was not detected following a recharge event which occurred only three days after it was applied.

Environmental and Management Conditions: In addition to their mobility in water, the potential for pesticides to be leached to groundwater also depends on the conditions under which they were applied.

The longer the period between pesticide application and the first precipitation event, the more time there will be for pesticides to be volatilized, sorbed, biologically degraded, or taken up by the crop.

The spring and early summer of 1992 were unusually dry until mid-June. As a result of the extremely low antecedent moisture conditions, rainfall in June served to replenish moisture reserves but resulted in very little recharge to the water table, as evident from Figure 2. Therefore, there was more time between application and recharge for pesticides to be sorbed or degraded.

The mitigating effect of the dry spring and summer on the leaching of pesticides was shown during monitoring conducted during the spring and summer of 1992 at four other sites in southern Alberta (Hill et al. 1993). Pesticides were not detected in any samples collected following rainfall and irrigation events in June and July. At one of the sites, samples were collected under similar conditions in July of 1991, and after re-application of herbicides followed by heavy irrigation in October of 1992. Both of those sets of samples did contain herbicides (Hill et al. 1993).

Location of Water-Table Wells: Water-table well 1 is located in the lowest point in Study Area 2, and it exhibited the greatest water-table response to recharge events (Figure 2). Therefore, the detection of phorate at this location is consistent with groundwater flow directions. Water-table well 6, however, is located at the highest point in the Study Area, and is not within the cropped area.

The detection of metribuzin only at water-table well 6 may be a result of sampling bias. Due to the very slow response of water-table well 6 following bailing, it was the only well which was not thoroughly bailed immediately before sampling. This suggests that metribuzin may be degraded or sorbed over time in the formation, but is preserved once ground water is inside the well.

Study Area 3

Rodvang et al. (1992) found that the highest pesticide levels tended to occur during the first precipitation or irrigation event following pesticide application. At Study Area 3, however, triallate was not detected until third irrigation or rainfall event following application. Dry antecedent moisture conditions probably restricted groundwater recharge during the first two events, as noted above.

CONCLUSIONS

Leaching of pesticides to groundwater is greatly dependent on environmental and management conditions. The lack of significant pesticide detection during the current investigation suggests that under some conditions, pesticides can be applied without adverse environmental effects. However, even though pesticides were mainly undetectable in groundwater during the current investigation, it is

possible that pesticides will be leached to groundwater if recharge occurs soon after application.

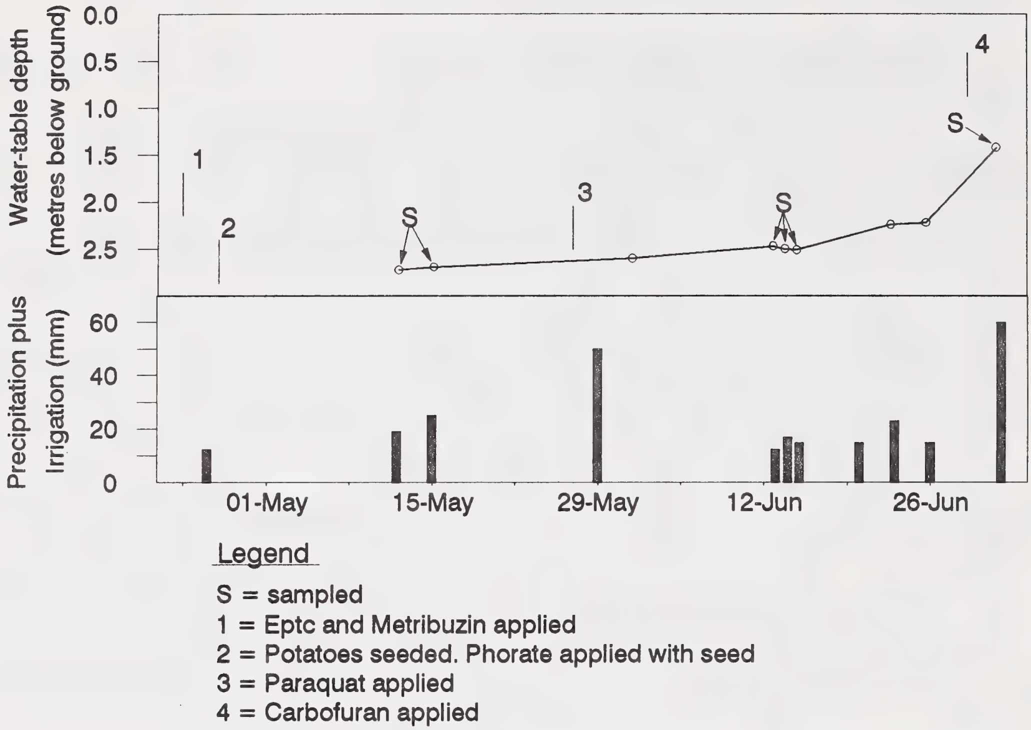

Figure 2. Water-table depth and precipitation plus irrigation at Study Area 2.

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HERBICIDE MONITORING UNDER A CHEMIGATED POTATO FIELD

M. Rigby[1], G. Cook[2], and S.J. Rodvang[3]

INTRODUCTION

Chemigation, or the application of agricultural chemicals through modified irrigation systems, is a relatively new practice. An applied research project was developed by the Irrigation Branch of Alberta Agriculture to demonstrate chemigation and Low Input Precision Application (LEPA) technology at the Agriculture Canada Research Station in Vauxhall, Alberta, (Cook et al. 1992).

There is a potential for pesticides applied using chemigation to be leached to groundwater. To address this concern, shallow groundwater below the site was monitored for the pesticides applied using chemigation.

METHODS

Land Use and Chemigation Method

Potatoes were planted in concentric rows under the pivot circle. Insecticides were applied through a centre pivot which had been modified with an agri-injector. Safety devices were used on the injector to prevent chemicals from contaminating the water source by backflow. The pivot was modified to accommodate three types of low pressure sprinkler heads: Senninger Quad-spray, Nelson spinner and Senninger Low Drift Nozzles.

Each chemigation event was followed by irrigation to flush chemicals from the pivot system. The amount of water required to flush chemicals from the irrigation system was determined as follows. A concentrated salt solution was injected into the pivot and the electrical conductivity (EC) of water discharged from the last nozzle was measured at one minute intervals. Irrigation continued until the EC returned to levels recorded before injecting the salt solution.

Installation of Stainless-Steel Water-Table Well

A stainless- steel water-table well was installed on June 1, to a depth of four metres in the potato plot. The well was made from a tubular length of stainless-steel, slotted at 4-cm intervals over the lower three metres. A stainless-steel end-cap was welded on the bottom, and a screw-locking top cap was added after installation.

The well was washed with acetone followed by de-ionized water, and wrapped tightly in brown paper for transport to the field. Solid-stem augers and drilling bits were pressure-washed with hot soapy water, followed by a rinse with acetone, and a final rinse with de-ionized water before drilling. Augers were then wrapped in large plastic bags for transport to the field.

The upper 15 cm of soil was removed before drilling. Surface soil and drill

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cuttings were not allowed to fall into the drill holes. The water-table well was backfilled with washed silica sand around the screened interval, followed by bentonite to the ground surface.

Hydraulic Conductivity Testing

The hydraulic conductivity of the deposit to a depth of four metres was determined from the water-table well. The well was bailed, and the water-level was monitored at two to five minute intervals until it recovered to equilibrium.

Chemigation and Sampling Events

Three different insecticides were applied using chemigation between July 21 and August 19, 1992. All insecticides were applied at their maximum recommended rate (Table 1). Ambush (active ingredient permethrin) was applied on July 21, Fenvalerate was applied on August 12 and August 14, and Pirimor (active ingredient Pirimicarb) was applied on August 19. About 12 mm of irrigation water were applied with each chemigation event.

Groundwater samples for organic analysis were collected on July 24, August 6, August 19, and September 16 (Table 1). Sampling events were timed to occur once the water-table rose following an irrigation event.

Table 1. Sampling Record

Date	Analytical Results: Permethrin (ppb)	Analytical Results: Pirimicarb (ppb)	Comments
01-June-92			stainless steel water-table installed
10-June-92	sample not analyzed due to budget constraints		
21-July-92			permethrin applied at 192 ml per hectare
24-July-92	N.D.	N.D.	
30-July-92	sample not analyzed due to suspected contamination		
06-Aug-92	N.D.	N.D.	
12-Aug-92			fenvalorate applied at 333 ml per hectare
14-Aug-92			fenvalorate applied at 333 ml per hectare
19-Aug-92	N.D.	4.7	pirimicarb applied at 543 grams per hectare
28-Aug-92	N.D.	N.D.	
16-Sept-92	N.D.	0.64	
Detection Limit	2.0	0.20	
QA/QC-% Spike Recovery	130	119	

N.D. = not detectable

Groundwater Monitoring

Water-table depth was monitored every day, to every few days, throughout July and August of 1992.

Groundwater samples for chemical analysis were collected in high density polyethylene sample bottles using a stainless steel bailer. The bailer and sample bottles were triple-washed in acetone and distilled water before sampling. Samples were stored at -40°C until they were analyzed on November 5.

Organic Analysis of Water Samples

Water samples were partitioned with dicloromethane (DCM) at a neutral pH. The DCM extract was concentrated to a low final volume and stored at -20°C until analysis by gas chromatograph/mass selective detection. The samples were analyzed for permethrin and pirimicarb. Fenvalerate was not analyzed because the laboratory did not have the capability.

RESULTS

Chemical Flushing

Monitoring the EC of irrigation water following the injection of a concentrated salt solution indicated that salt was flushed from the pivot within three minutes.

Hydraulic Conductivity and Water-Table Level

The site was underlain by material with a hydraulic conductivity of 7×10^{-7} m s^{-1}. The water-table was about 1.9 m deep until July 29, when it rose to 1.2 m following a 27 mm rain on the previous day. The water-table was generally at a depth of about 1.5 m for the remainder of the season (Figure 1).

Insecticides Detected in Groundwater

Permethrin was not detected in any of the four samples. Pirimicarb was not detected before its application, but was detected in both samples collected following its application, at a maximum level of 4.7 ppb (Table 1).

DISCUSSION

There are currently no guidelines for the maximum concentration of pirimicarb allowed in water.

The conditions of this investigation were typical of those in irrigated areas of southern Alberta. For a given set of climatic, subsurface and management conditions, the frequency of detection of herbicides will depend mainly on the extent to which they are used, their rate of degradation, and their mobility in water. The distribution coefficient normalized to the amount of organic carbon in the soil, or Koc, measures the amount of a chemical which will be sorbed to a given soil, relative to the amount in solution.

Koc values calculated using the method of Karickhoff (1981) were as follows: fenvalerate = 6.54, permethrin = 5.91, pirimicarb = 1.37. The relatively low Koc value for pirimicarb is a function of its high solubility. Pirimicarb has a solubility of 2700 mg L^{-1}, whereas permethrin and fenvalerate are nearly insoluble (Royal Society of Chemistry 1983).

The Koc values for permethrin and fenvalerate indicate that they are strongly sorbed to soil, and therefore they have a low probability of being leached to groundwater. The Koc value for pirimicarb indicates that it has a "moderate mobility" according to the classification of McBride et al. (1988).

Water-table monitoring indicated that recharge had not yet occurred when the first permethrin sample was collected (Figure 1). Although permethrin has a relatively high Koc, it is possible that it may be leached to groundwater if recharge occurs soon after it is applied.

The results of this investigation are consistent with the findings of Rodvang et al. (1992) that herbicide concentrations tend to be highest at the beginning of irrigation events, with decreasing levels over time. The sample which contained 4.7 ppb pirimicarb was collected on the same day it was applied. The concentration of pirimicarb may have increased to a higher level on subsequent

days. The continued detection of pirimicarb nearly one month after it was applied, and after another 65 mm of rain had fallen on the site, indicates that it is a relatively persistent chemical.

Rodvang et al. (1992) found that the highest herbicide levels were detected in groundwater when irrigation or rainfall occurred soon after herbicides were applied. This suggests that applying mobile pesticides using chemigation will promote leaching to groundwater.

CONCLUSIONS

The results of this investigation indicate that pesticides are leached to groundwater during chemigation under some conditions in southern Alberta. The effect which pesticide-type, environmental and management conditions exert on pesticide leaching requires further investigation.

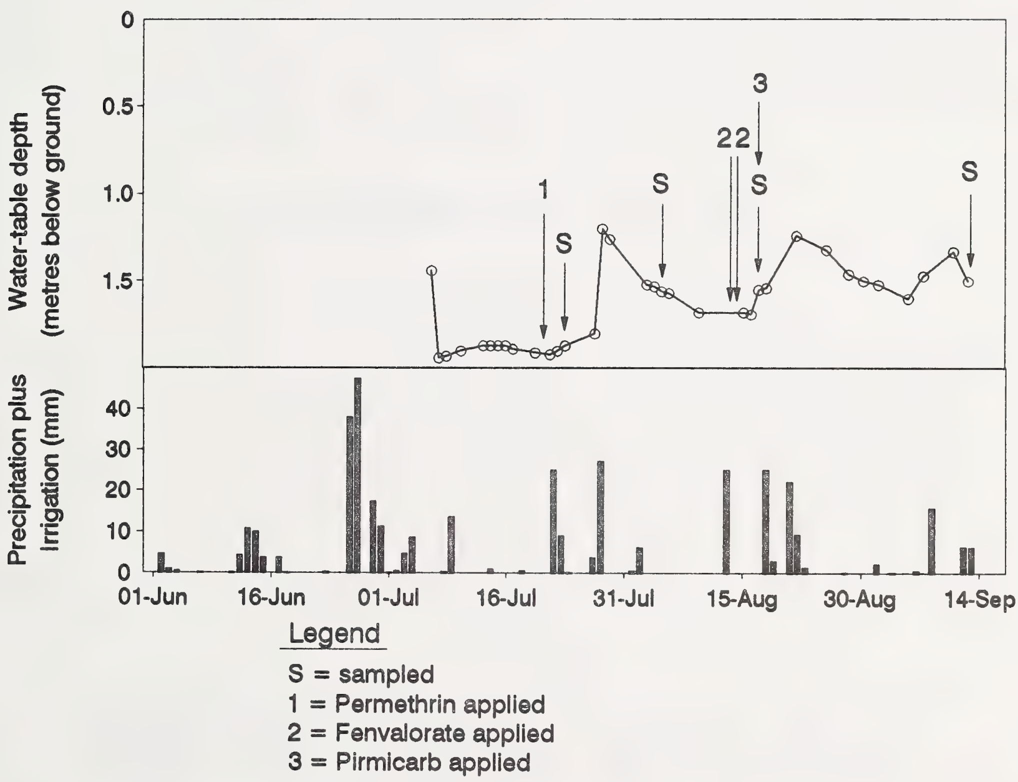

Figure 1. Water-table depth and precipitation plus irrigation.

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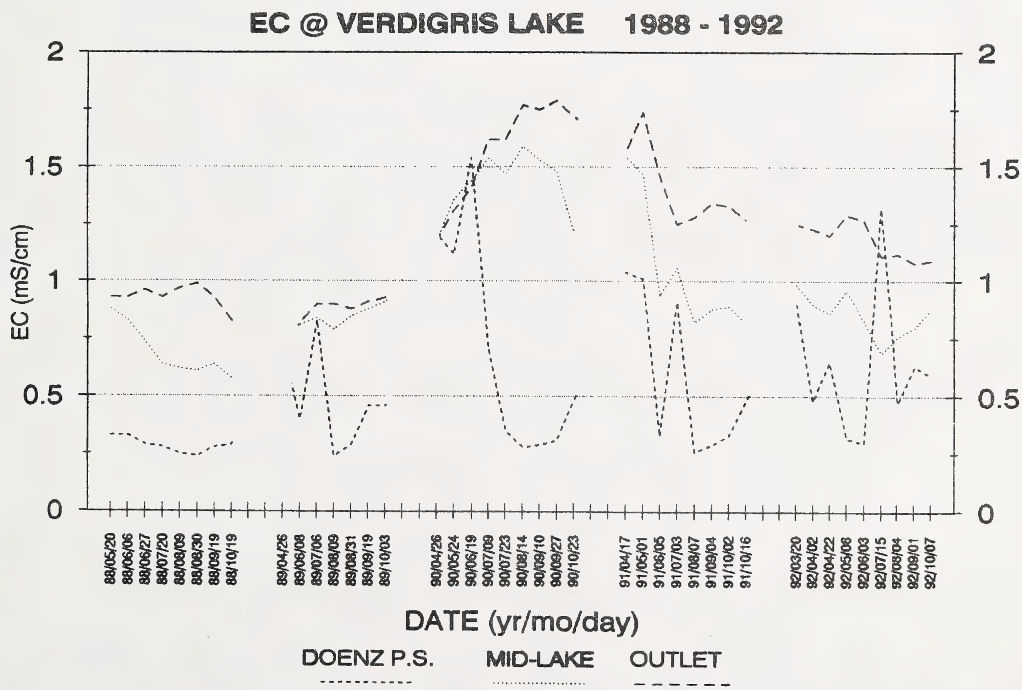
VERDIGRIS LAKE WATER QUALITY - 1992

G. Cook[1] , J. Ganesh[2] , L. Kwasny[1]

INTRODUCTION

Irrigation water quality in Verdigris Lake has been monitored by numerous parties since 1983. Water users and the irrigation district have always been concerned that the electrical conductivity (EC) and sodium adsorption ratio (SAR) have exceeded the safe limits for irrigation. High evaporation rates from the lake surface, and low irrigation demand make management of the reservoir to minimize salt content difficult.

After several years of steady improvement, water quality in the lake deteriorated above safe levels throughout the summer of 1989 and 1990. In 1991, quality improved substantially. This improvement has continued throughout 1992, however, water quality levels at the downstream end of the lake continue to be above the safe levels outlined by Alberta guidelines. The flow monitoring carried out by the hydrometric unit of the irrigation branch, coupled with water sampling and irrigation monitoring by the irrigation branch office in Taber for 1992 are presented in this report. A water and salt balance for the reservoir has been estimated for the 1992 irrigation season.



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METHOD

WATER BALANCE

Lake inflow and spill are measured by automated flow metering stations installed in 1991. The incoming flow monitoring station also has a rain gauge and a salinity sensor. Water Survey of Canada maintains a flow measuring station on Hummel's Coulee. The station is located approximately 2 kilometers from the lake. Flow values from this site will not be used because of its distance from the lake. This makes it difficult to estimate the volume of water actually making it to the lake. Hummel's Coulee will however be referred to when analyzing water and salt balances. In order to record accurate runoff and water quality information, monitoring at the point where Hummel's Coulee enters the lake would be required.

Precipitation was recorded at three locations along the length of the lake (SITES #2, #3, & #4). Precipitation is treated as an inflow to Verdigris Lake and will be referred to as rain inflow. Evaporation was determined at a location on the downstream end of the lake using a Class A pan. Pan evaporation rates were converted to lake evaporation rates using the formula:

Lake Evaporation = (Pan Evaporation + 5.74) / 1.69

This formula is based on a comparison of several years of shallow lake evaporation estimates provided by Alberta Environment and Class A pan evaporation data for Lethbridge.

Evaporation is treated as an outflow from Verdigris Lake and will be referred to as evaporation loss. Evaporation loss minus rain inflow will be referred to as surface losses.

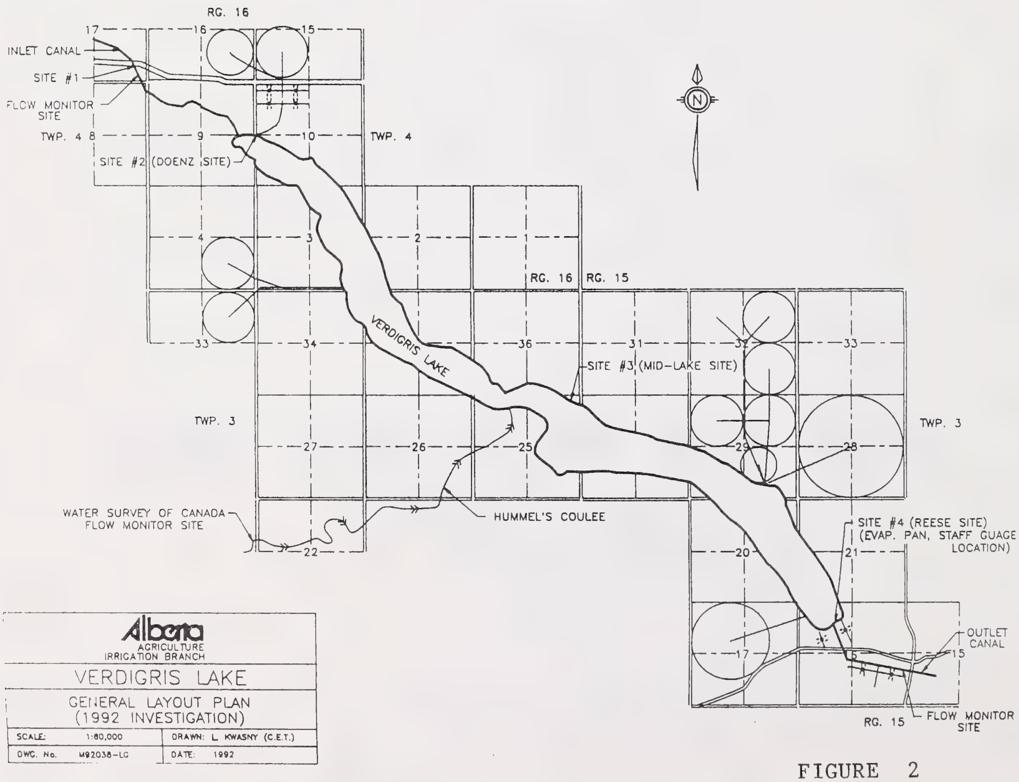

FIGURE 2

2076 acres of land were irrigated in 1992 from pump stations located between the second and third flow monitoring sites. Hours of operation for these pumping units were tallied on a weekly basis to determine irrigation withdrawals from Verdigris Lake. Pumping rates were determined from flow tests and design specifications.

Weekly lake volume was determined using a staff gauge at the south end of the lake. Using the staging curve provided by Associated Engineering, the elevation was converted to a lake volume and surface area. Evaporation and precipitation were matched to the weekly lake surface area to determine a loss or gain in acre feet. Because wind distorts the true depth of the lake weekly water balances are difficult to compute, therefore, water balance estimates are done on a season long basis.

Water balance comparisons in acre-feet from 1991 and 1992 are as follows:

Year	Spill	Surface Losses	Irrigation	Total Outflow	Total Inflow
1991	5,361	2,997	1,745	10,103	11,774
1992	4,333	2,504	2,201	9,038	9,283

SALT BALANCE

Using the water volumes calculated from the collected data, a salt balance for the lake was estimated. The salt load carried by the water was computed using the formula:

TDS (mg/l) = 765(EC)1.087 (Cheng et al. 1983)

Weekly water samples were collected at the inlet canal and three sites along the north-east shore by irrigation branch staff. Pumping volumes were grouped by proximity to each sample site and the tonnes of salt removed were determined. The tonnes of salt removed by spill was calculated using the water quality results collected at the lake outlet (SITE #4) and the flow values recorded at the automated metering site downstream of Verdigris Lake. The addition of a salinity sensor to the automated metering site immediately upstream of Verdigris Lake was used to calculate the daily tonnes of salt entering through the inlet canal. This addition aided in isolating deteriorating water quality as a result of runoff during periods of precipitation.

In an attempt to represent a more accurate estimation of the actual salt content of the lake itself, water samples were collected throughout its entire length using a boat. Using these water samples and their location relative to the weekly samples collected from the three shore locations, the volume of the lake represented by each shore sample was determined. This was done by partitioning the lake into zones of similar water quality and using the area of the zone to determine volume. This method assumed that the lake has a very similar bottom profile throughout its entirety.

Using this method, it was determined on July 15, 1992 that the Doenz site water quality represented 25% of the lake volume, the mid-lake sample represented 60% of the lake volume, and the Reese site water samples represented 15% of the lake volume.

Seepage meters were installed in the lake at Sites #2 and #3. Weekly observation indicated that there was ground water movement into the lake. Water samples obtained from the seepage meters were similar to the lake samples at these sites. The irrigation branch is hoping to take deep core samples early in 1993, if ice conditions permit, to determine the salt content of bed materials. Preliminary investigations show the surficial bed material to be high in salt concentration.

Water sampling in 1992 included Ca, Mg, Na and K cation analysis and SO4,

Cl, CO3, HCO3, NO3-N anion analysis. This type of analysis allowed us to calculate an adjusted SAR (RNa) according to the equation developed by Saurez in 1981. RNa takes into account carbonate and bicarbonate ions, as well as sodium, calcium and magnesium. RNa for the lake outlet water qualities proved to be slightly higher than the SAR calculated by standard methods.

RESULTS

WATER BALANCE

For the period March 25 to October 21, 1992 canal inflow was measured at 9,283 ac-ft and rain inflow was estimated at 1,792 ac-ft for a total inflow of 11,075 ac-ft. Outflow from spill was measured at 4333 ac-ft, irrigation was estimated at 2201 ac-ft, and evaporation losses were estimated at 4296 ac-ft for a total outflow of 10,830 ac-ft. The difference between inflow and outflow indicates an increase in lake volume of 245 ac-ft. Using the Verdigris Lake Staging Curves and the staff guage located at the bottom end of the lake, the March 25 lake volume was 8350 ac-ft and the October 21 lake volume was 8715 ac-ft resulting in an increased volume of 365 ac-ft. The difference between the measured volume and the expected volume is 120 ac-ft. A volume of 120 ac-ft. is equivalent to 1.3% of the average lake volume for the season or 19mm of lake depth. This does, however, indicate an increase in lake volume which was not accounted for through monitoring, assuming the staging curves are accurate. The most plausible explanations for this increase is runoff inflow from Hummel's Coulee and other coulees entering Verdigris Lake or ground water discharge into the lake.

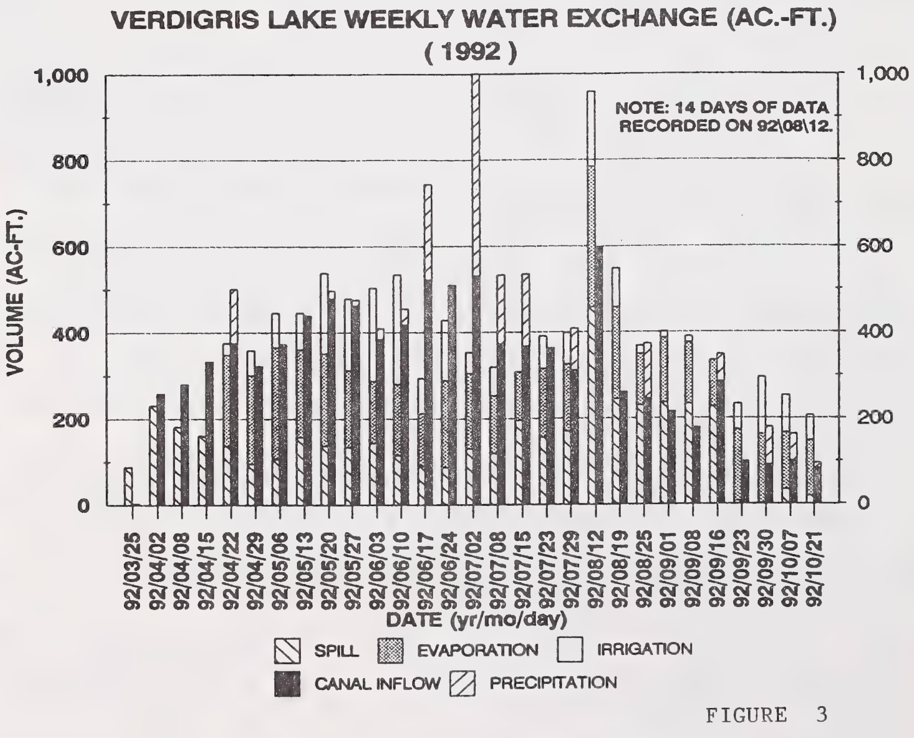

FIGURE 3

SALT BALANCE

Using the data collected from March 25 to October 21, 1992, salt introduced into the lake was 4054 tonnes, 4827 tonnes were removed by spill, and 1801 tonnes removed by irrigation, for a net loss of 2574 tonnes.

Using the shore sampling method of determining lake salt content, initial lake salt content on March 25, 1992 was 7987 tonnes and the final content on October 21 was 7507 tonnes. This represents a net removal of 480 tonnes from the lake. Our weekly salt balance figures estimate the expected salt removal to be 2574 tonnes for a difference of approximately 2094 tonnes. This indicates an increase in lake salt which was not accounted for through monitoring. An increase of this amount may have resulted from runoff events down Hummel's Coulee and other coulees leading into the lake or salt diffusion from seepage through the bed material. Salt content based on shore sampling is quite arbitrary and may not accurately reflect the true salt content of the lake.

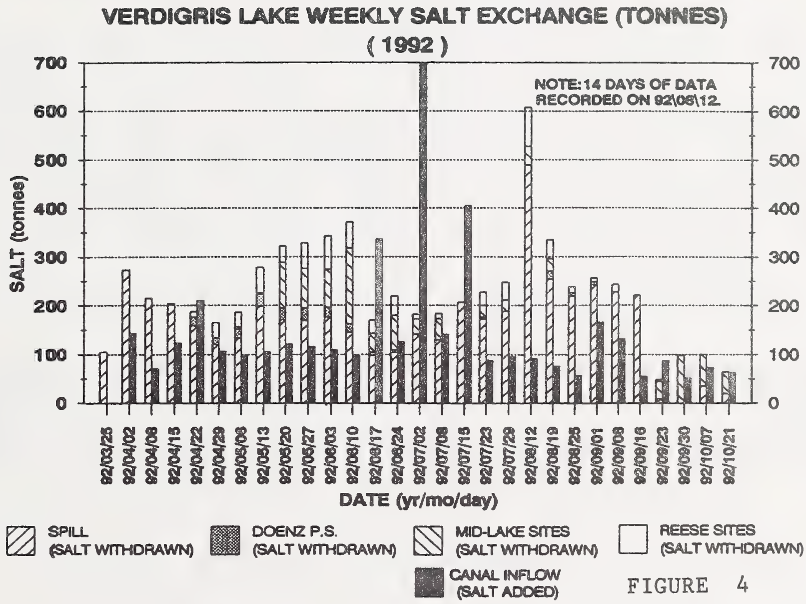

FIGURE 4

CONCLUSION

Water quality improved over 1991 and 1992 but still remains above safe levels at the outlet.

In 1992 spill and surface losses were approximately three times the irrigation withdrawals, in comparison to 1991 where the spill and surface losses were five times the irrigation withdrawals.

The highest irrigation withdrawals continue to occur early in the season when water quality tends to be the poorest.

Dense weed growth continues to hinder water movement down the length of the lake.

The 2,000 tonnes of salt unaccounted for by monitoring in 1992 is a concern. Most possible sources are run-off and groundwater discharge into the lake.

Adjusted SAR (RNa) is approximately 10% higher than the SAR for the lake water at the outlet.

ELIMINATION OF AQUATIC WEEDS IN IRRIGATION CANALS USING TRIPLOID GRASS CARP YEAR IV

Prepared on Behalf of the Committee on
Biological Control of Aquatic Vegetation
by E. D. Lloyd (Chairman)[1]
S. Jonas (Vice-Chairman)[1]
J. Stewart[1]

INTRODUCTION

The objective of this five-year cooperative research study, is to study the utilization of sterile triploid grass carp (Ctenopharyngodon idella) to provide an overall biological control of problem aquatic vegetation in the 8000 kilometres of open canal systems in Alberta.

The five-year research plan was initiated by Alberta Agriculture in cooperation with Alberta Forestry, Lands and Wildlife, Alberta Environment, Agriculture Canada and the Alberta Irrigation Projects Association. In addition, the Lethbridge Community College (LCC) and University of Lethbridge are involved.

In year one of the study (1988/89), approximately 5000 four-day-old larval grass carp were imported into Alberta from Florida. The fish were raised for one year under quarantine conditions at the Alberta Environmental Centre in Vegreville. Twelve component task studies were undertaken by members of the committee as listed.

In year two (1989/90), one thousand of the certified fish were stocked in shallow dugouts in southern Alberta. Fish were over-wintered in deep oxygen-rich dugouts.

In year three (1990/91), the fish were stocked into a flowing irrigation canal with no return flow to a river system. Results were positive, with additional stockings recommended. Additional fish were imported and raised under quarantine to replace those lost to normal mortality and laboratory testing.

In the fourth year of the study the following tasks were performed by a professional committee member(s) as named.

DISCUSSION OF TASKS

Grass Carp Stocking, Growth and Survival in Summer and Winter Dugouts - 1991/92 (R. Beck)

In the summer of 1991, ten dugouts were stocked with grass carp in the Raymond Irrigation District (RID) and on Agriculture Canada sites. Three dugouts were selected as over-wintering dugouts and received fish in the fall of 1991. All of the dugouts were monitored weekly or biweekly for temperature, dissolved oxygen, ammonia nitrogen and qualitative plankton analysis. In each dugout qualitative assessments were made throughout the summer on weed control.

Based on the initial stocking of 770 grass carp in all of the summer and winter dugouts in 1991/92, there was a 68.3% survival rate and an average growth increment of 59.6%.

Ten dugouts were analyzed on May 25, 1992 for sodium cation levels. The results indicate a relationship between grass carp over-wintering losses and low

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sodium levels.

Raymond Irrigation Canal - Stock Fish, Monitor and Recovery - 1991 (R. Beck)

Two reaches of irrigation canal were stocked in the spring of 1991 to determine fish behaviour and weed control efficacy in a flowing system, and to test methods of fish stocking, containment and recapture from a canal environment. Reach #1 was stocked at a density of 85 kg of triploid grass carp per hectare of canal. Reach #2 was stocked at a density of 42.5 kg/ha; these fish were 84% larger than those stocked in Reach #1. Reach #2 was re-stocked on July 02 and July 23 to compensate for estimated losses of fish. This resulted in an estimated density of 53.0 kg/ha on July 23. Observations conducted throughout the summer and fish retrieval on October 10 revealed poor survival (2.1%) and poor fish growth (48%) in Reach #1.

There was no evidence to suggest that the structural integrity of barriers contributed to fish losses from the study area.

Indoor Rearing of Triploid Grass Carp (Ctenopharyngodon idella) in Artificial Tanks (R. Beck)

Approximately 650 grass carp were introduced from the RID canal and summer dugouts into three tanks at the LCC grass carp rearing facility in the fall of 1991. Grass carp in Tanks #1 and #2 were fed at a rate of 2.5 - 4% body weight per day. Water temperatures averaged 22.2°C. The fish in Tank #3 were fed a daily maintenance diet of 60 g of fresh cuttings of winter wheat and/or barley. Water temperature in this tank was held at 15.7°C.

After 30 weeks, 155 grass carp in Tank #1 had a growth weight increment of 234% while 469 grass carp in Tank #2 had a growth weight increment of 365%. The 71 grass carp in Tank #3 had a weight loss of 7.9%.

Grass Carp Stocking, Growth and Survival in Net Pens - 1991 (R. Beck)

Net pens provide a holding environment whereby fish can easily be retrieved and monitored for growth, survival and over-wintering diseases. Five floating net pens were constructed in the spring of 1991. Triploid grass carp (N = 521) were stocked at random densities and thereafter fed daily rations of grass clippings and floating catfish pellets throughout the summer.

Fish survival in all the net pens was high (mean = 79%), however growth weight was relatively low (mean = 14.3%) when compared to growth rates of similar size fish in free ranging dugouts. Factors contributing to low growth were: poor feeding behaviour, net pen density stress and frequent human disturbance.

In an attempt to evaluate and monitor the overwintering incidence of the gill parasite Chilodonella spp. in grass carp, 56 fish were stocked in a dugout (Fairfields) with a history of the gill parasite disease. These fish were held in net pen #1 throughout the winter. On March 10, 1992, four mortalities were reported and confirmed with Chilodonella sp. infections (Alberta Animal Health Division, AAHD). The remainder of the net pen fish population was heavily infected.

Fish Monitoring - Raymond Irrigation Canal (R. Beck)

In order to monitor fish movements within the canal, and to evaluate the use of artificially excavated pools, six large fish (425 - 534 g) were surgically implanted with radio transmitters. Each canal reach received 3 of the implanted fish. Fish movements were monitored weekly from the canal bank with a hand held Lotec receiver and YAGI antennae.

Pathology (G. Chalmers)

From January 1, 1992 to May 31, 1992, staff of the Regional Veterinary Laboratory, of the Animal Health Division in Lethbridge, examined 26 accessions of grass carp representing a total of 54 fish, 31 in 1991 and the remainder in 1992. Examinations included gross necropsy, evaluation of wet smears of skin and gills, histopathology, and occasionally, microbiology (bacteriology).

In five accessions, a Chilodonella spp. was found and judged to have been a major agent or to have the potential to cause serious disease in grass carp.

The examination of 21 dead carp from feeding tanks determined that these fish were thin and emaciated with completely depleted reserves of body fat. Feeding management was believed to be the major factor associated with this problem.

One particularly interesting observation was the degeneration of skeletal muscle (myopathy) in carp soon after placement in the irrigation canal in 1991. The findings suggested that the muscles of these fish were not well conditioned and that after placement in the canal, the exertion of working in moving water overwhelmed the aerobic capacity of muscle, and resulted in anaerobic glycolysis and the production of lactic acidosis, which in turn, induced the myopathy seen.

Overt nitrite toxicity was evident in tank-reared fish in two accessions, one in each year. A limited variety of other individual diagnoses were applied to fish in other accessions. These diagnoses include vertebral scoliosis (S-shaped spinal column), trauma, losses suspected to be associated with low values of oxygen in water, nephrocalcinosis and aneurysmal dilatations of vessels in gills, and inflammation and scarring of tail fins.

Alberta Environmental Centre Quarantine Facility (K. Smiley, J. Moore)

Following approximately 750 ploidy determinations conducted between April 16 and May 1, 1991, 600 health verified and certified triploid grass carp were released from Alberta Environmental Centre to the Committee on May 22, 1991. Included in these ploidy determinations were 39 blind quality assurance/quality control samples (5.2%). In addition to the blind QA/QC samples, a larger blood sample was taken from 73 (9.7%) grass carp for chromosome culture and karyotyping. As in previous years, all the blind samples were identified and all of the chromosome cultures confirmed the Coulter Counter determinations. Eighteen specimens were subjected for histopathology evaluations prior to being released to the Committee. All these evaluations, once again, confirmed the existing evaluations, as no viruses or pathogens were reported.

Grass Carp Efficacy - 1991 (R. Burland, J. Allan)

In the summer of 1990 grass carp were stocked, for the first time, into a screened off reach of the Raymond Main Canal. The stocking rate of 85 kg/ha was sufficient to provide near complete removal of weed growth from the stocked area. As a result, this rate can reasonably be established as a maximum.

For the 1991 season, grass carp were once again stocked into screened reaches of the Raymond Main Canal.

Random vegetation sampling commenced on May 31 and continued on a biweekly basis until September 25. There is some disagreement on the degree of aquatic vegetation control during the summer of 1991. The aquatic biomass harvesting studies suggested that the degree of control in Reach #2 was at least 80% using the larger size fish.

Predatory Fish Study (S. Jonas)

Only two stretches of canal, Reach #1 and Reach #2, were sampled in the fall of 1991. Northern Pike were the only predator fish found in the 1991 survey and

most of those were under 300 mm in length. The two largest fish found were in the 300 - 600 mm length class and these were still probably too small to prey on the large grass carp that had been stocked.

Containment and Fish Barriers (S. Jonas, L. Chew)

Before the 1991 irrigation season, three fish barriers were built to isolate two test sections in the Raymond Main Canal. All barriers have a maximum opening of 25 mm. Because the openings are small, trash collects on the upstream side of the barrier and will eventually block the flow of water. For that reason fish barriers #1, 2 and 3 are manually cleaned using a specially designed long handled rake.

Examination of the barriers at the completion of the 1991 irrigation season revealed no washouts or structural defects.

Studies investigating acoustic barriers revealed that grass carp initially avoided auditory stimuli, however, response dropped to nil after a series of repeated pulse trains. Fish moved away from the sound source when they were simultaneously exposed to bright light. At no time were fish observed approaching the sound source after movement away. This experiment highlights the need to review the efficacy of a purely acoustic fish barrier.

Water Temperatures (S. Jonas)

Most literature reviewed stated that the feeding rate of grass carp intensifies with increased water temperatures. Regular feeding starts at approximately 13°C and optimum feeding is reached at temperatures above 18°C.

Monitoring of water temperatures in canals started at the end of May, when irrigation water was turned into the ditches. Examination of the results show that maximum water temperatures of 18°C or higher are likely to occur over an eleven-week period, from the last week in June to the first week of August. Water temperatures were already above 13°C when readings were initiated in the middle of May and temperatures remained at this level until the first of October (approximately 137 days).

Brood Fish Program - 1992 (R. Beck)

Fundamental to understanding the potential of using grass carp in northern waters is the evaluation of maintaining and spawning brood fish in artificial tanks. The techniques required to spawn grass carp, incubate eggs and rear grass carp fry should be investigated and incorporated as a task of the biological weed control program. An examination of diploid fish spawning potential is a critical element required to assess the long term feasibility of the program.

CONCLUSIONS

1. The results of the quantitative indices used in the 1991 stocking model for the two canal study reaches are inconclusive because of high predation losses and the low water depths experienced throughout the summer.
2. The potential for rearing triploid grass carp under artificial conditions to a stockable size of 250 - 300 mm is viable from both an economic and biological perspective. Final grow-out of fish to larger sizes may be achieved in outdoor dugouts and ponds over the course of one summer growing season.
3. The maintenance of grass carp in net pens over extended periods of time is labour intensive and does not appear to be a viable alternative to natural fish foraging and rearing in dugouts.

4. Predatory fish are a threat to grass carp of a certain size. Losses attributed to fish predation diminishes as grass carp size increases.
5. Modified fish barriers #1, #2 and #3 functioned satisfactorily during the 1991 irrigation season.
6. The presentation of acoustic stimuli to small groups of grass carp produced negative results, however, a combined tone/light stimulus produced clear avoidance behaviour.

SURFACE WATER QUALITY MONITORING FOR SALINITY, SODICITY AND NITRATES IN SOUTHERN ALBERTA IRRIGATION RETURN FLOW STREAMS, 1992

G. Greenlee, M. Peters and P. Lund[1]

INTRODUCTION

The quality of irrigation water is considered excellent in the irrigation districts of southern Alberta, with average salinity levels ranging from 0.28 to 0.36 dS m^{-1}, average sodicity levels ranging from 0.3 to 0.6 and average total dissolved solids ranging from 154 to 212 mg L^{-1} (Hamilton et al. 1982). The report of the Bow River Water Quality Task Force in 1991 cited irrigation return flows as direct sources of pollutants discharged into the Bow River and its tributaries.

The objectives of this study were to: monitor surface water quality in selected return flow streams of southern Alberta irrigation districts, compile a database on surface water quality in irrigation return flow streams of southern Alberta and assess changes in water quality between selected water diversion locations and return flow streams.

METHODS

Surface water quality was monitored weekly from May through September, 1992, in four return flow streams and at four water diversion locations in three irrigation districts (Figure 1). Water samples were analyzed for pH, electrical conductivity (EC), soluble cations (calcium, magnesium, sodium, potassium), sodium adsorption ratio (SAR), soluble anions (sulfate, chloride, carbonate, bicarbonate, nitrate), and total dissolved solids (TDS) using standard analytical techniques (Clesceri et al. 1989).

RESULTS AND DISCUSSION

Salinity, sodicity and nitrate levels and TDS were low at all four diversion sites, with EC values of 0.23 to 0.44 dS m^{-1}, SAR values of 0.3 to 0.7, nitrate values of 0 to 0.6 mg L^{-1} and TDS values of 190 to 360 mg L^{-1} (Table 1). Salinity and TDS were highest in May, decreased during June through August and increased in September (Figure 2, graph for TDS not shown). Sodicity fluctuated throughout the irrigation season (Figure 3). Nitrate was not detected at one diversion site and levels were very low at the other three sites. Nitrate ranged from 0 to 0.6 mg L^{-1} during May, with none detected thereafter at two sites, and levels ranged from 0 to 0.6 mg L^{-1} during May and July at one site with none detected during the other months.

Average water quality of return flow streams was somewhat poorer than at water diversion sites, with salinity levels ranging from 0.24 to 1.1 dS m^{-1}, sodicity levels ranging from 0.3 to 1.5, nitrate levels ranging from 0 to 1.9 mg L^{-1} and TDS levels ranging from 190 to 985 mg L^{-1} (Table 1, Figures 2 and 3). Constituent levels in two return flow streams were only marginally higher than at the respective water diversion sites, with EC values of 0.24 to 0.4 dS m^{-1}, SAR values of 0.3 to 0.7, nitrate values of 0 to 0.6 mg L^{-1} and TDS values of 190 to 340 mg L^{-1}. This was not surprising , since most irrigation return flow water

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simply flows through irrigation canals. The water is diverted for irrigation, but flows through canals into return flow streams, without being used for irrigation. A small fraction of irrigation return flow water originates as surface runoff from irrigated lands, mostly from flood irrigation methods.

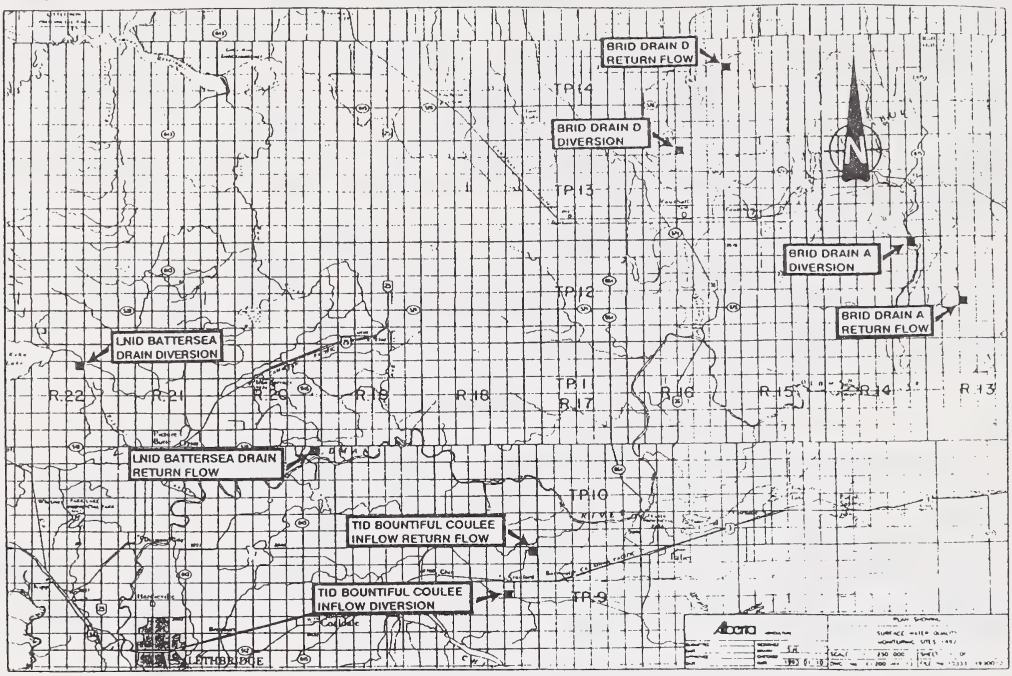

Figure 1. Surface water quality sampling locations.

Table 1. Salinity, sodicity, nitrate and TDS levels from water diversion sites and in return flow streams.

	LNID[2] BATTERSEA DRAIN		TID[2] BOUNTIFUL COULEE		BRID[2] DRAIN "A"		BRID[2] DRAIN "D"	
Parameter	Diversion	Return Flow	Diversion	Return Flow	Diversion	Return Flow	Diversion	Return Flow
EC (dS/m)	0.29 (0.02)	0.46 (0.23)	0.25 (0.05)	0.28 (0.06)	0.34 (0.08)	0.59 (0.17)	0.35 (0.02)	0.36 (0.02)
SAR	0.41 (0.08)	0.65 (0.30)	0.37 (0.09)	0.42 (0.11)	0.55 (0.13)	1.00 (0.29)	0.54 (0.08)	0.55 (0.06)
NO_3-N (mg/L)	0.05 (0.17)	0.27 (0.44)	0.00 (0.00)	0.00 (0.00)	0.08 (0.21)	0.11 (0.24)	0.03 (0.13)	0.13 (0.26)
TDS[2] (mg/L)	245 (20)	382 (199)	212 (45)	239 (50)	274 (67)	474 (143)	285 (19)	298 (19)

[1] Mean values with standard deviation in parenthesis.

[2] TDS = Total dissolved solids; LNID = Lethbridge Northern Irrigation District; TID = Taber Irrigation District; BRID = Bow River Irrigation District.

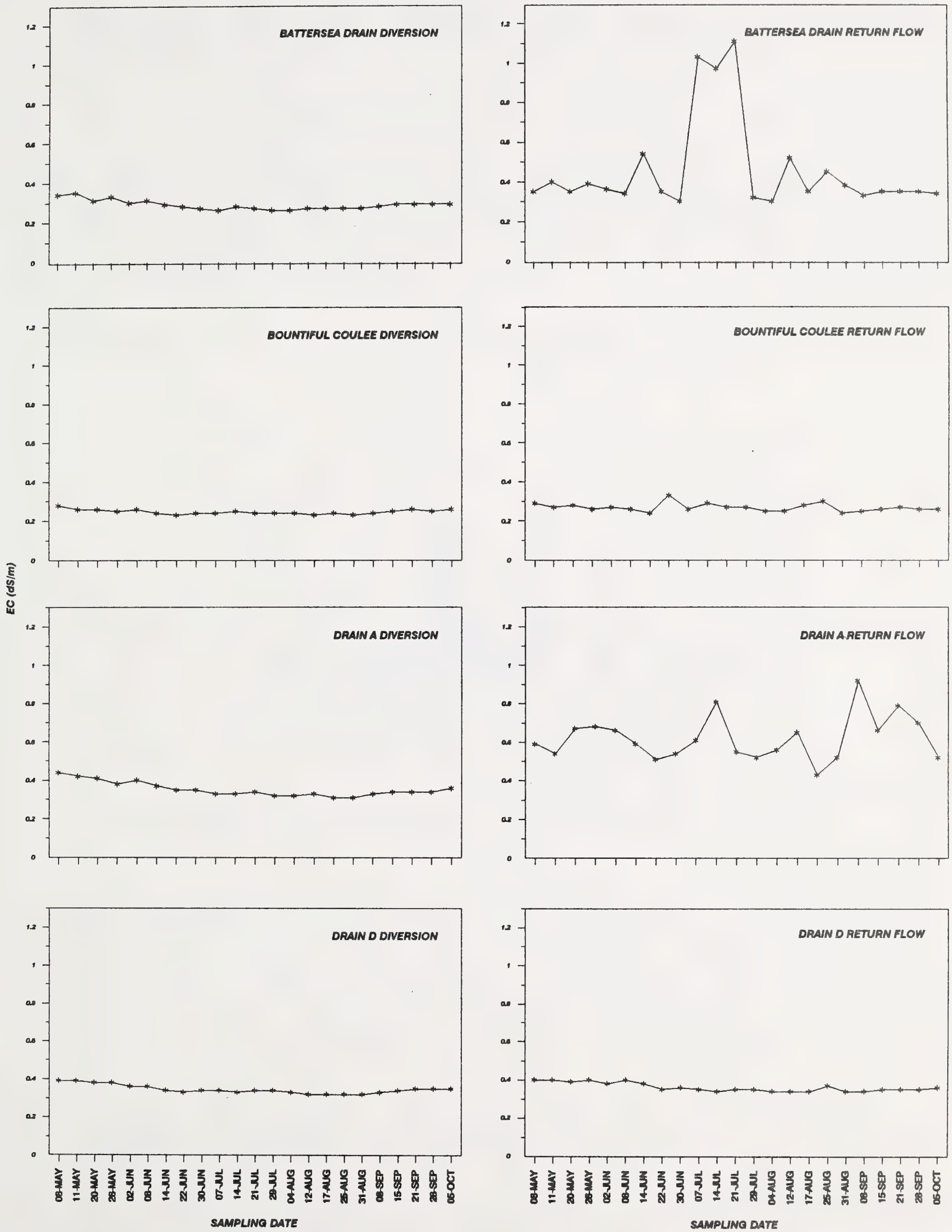

Figure 2. Seasonal salinity levels at water diversion sites and in return flow streams.

Figure 3. Seasonal sodicity levels at water diversion sites and in return flow streams.

Today, about 75 percent of the irrigation in southern Alberta's irrigation districts is by sprinkler methods (Paterson 1991). Surface runoff is generally not a problem under properly managed sprinkler irrigation methods (Paterson 1990).

Salinity and sodicity levels, and total dissolved solids were elevated in two return flow streams, with EC values of 0.3 to 1.1 dS m^{-1}, SAR values of 0.4 to 1.5 and TDS values of 235 to 985 mg L^{-1}. Drainage areas feeding these return flow streams may have more flood irrigation than those with lower constituent levels. Fluctuations in constituent levels also appeared to correlate well with seasonal precipitation events (Figure 4). Constituent levels peaked in July in one return flow stream, and September in the other. Nitrate was not detected in one return flow stream, and levels ranged from 0 to 0.6 mg L^{-1} during May through July, with none detected thereafter, in two other streams. Levels ranged from 0 to 0.6 mg L^{-1} throughout the irrigation season in the fourth stream, and peaked at 1.9 mg L^{-1} on July 14.

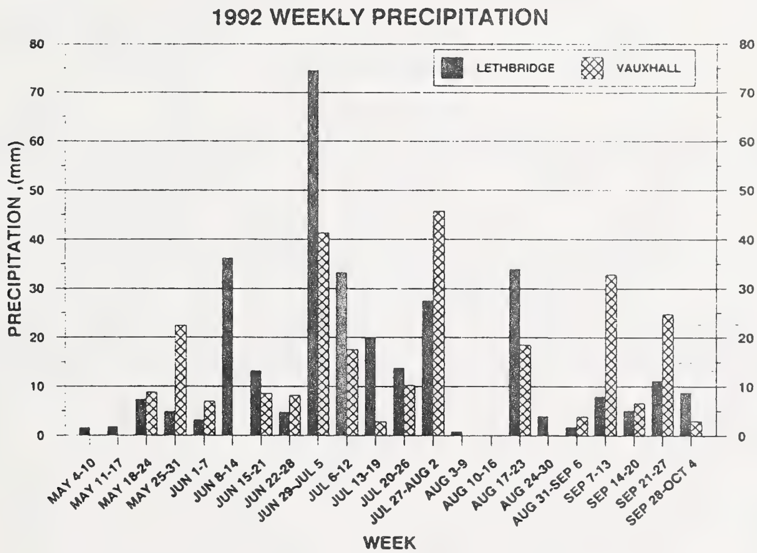

Figure 4. 1992 Seasonal precipitation at Lethbridge and Vauxhall.

CONCLUSIONS

Salinity, sodicity and nitrate levels, and total dissolved solids indicated a slight degradation in water quality between diversion sites and return flow streams, but most values were well below the Canadian Water Quality Guidelines for human and livestock consumption, and irrigation (CCREM 1992; Alberta Agriculture 1992). Exceptions were the elevated levels of total dissolved solids (up to 985 mg L^{-1}) in two return flow streams, which were above the guideline of 500 mg L^{-1} for human consumption. Constituent levels were similar to those reported previously for southern Alberta (Bolseng 1991; Bolseng 1992).

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SURFACE WATER QUALITY MONITORING FOR TRACE ELEMENTS AND PESTICIDES IN SOUTHERN ALBERTA IRRIGATION RETURN FLOW STREAMS, 1992

G. M. Greenlee, T. M. Peters and P. D. Lund[1]

INTRODUCTION

The report of the Bow River Water Quality Task Force in 1991 cited irrigation return flows as direct sources of pollutants discharged into the Bow River and its tributaries. The objectives of this study were to: monitor surface water quality in selected return flow streams of southern Alberta irrigation districts, compile a database on surface water quality in irrigation return flow streams of southern Alberta, and assess changes in water quality between selected water diversion locations and return flow streams.

METHODS

Surface water quality was monitored weekly from May through October 5, 1992, in four return flow streams and at four water diversion locations in three irrigation districts (Figure 1). Water samples were analyzed for selected trace elements (arsenic, cadmium, copper, lead, mercury, selenium) using atomic

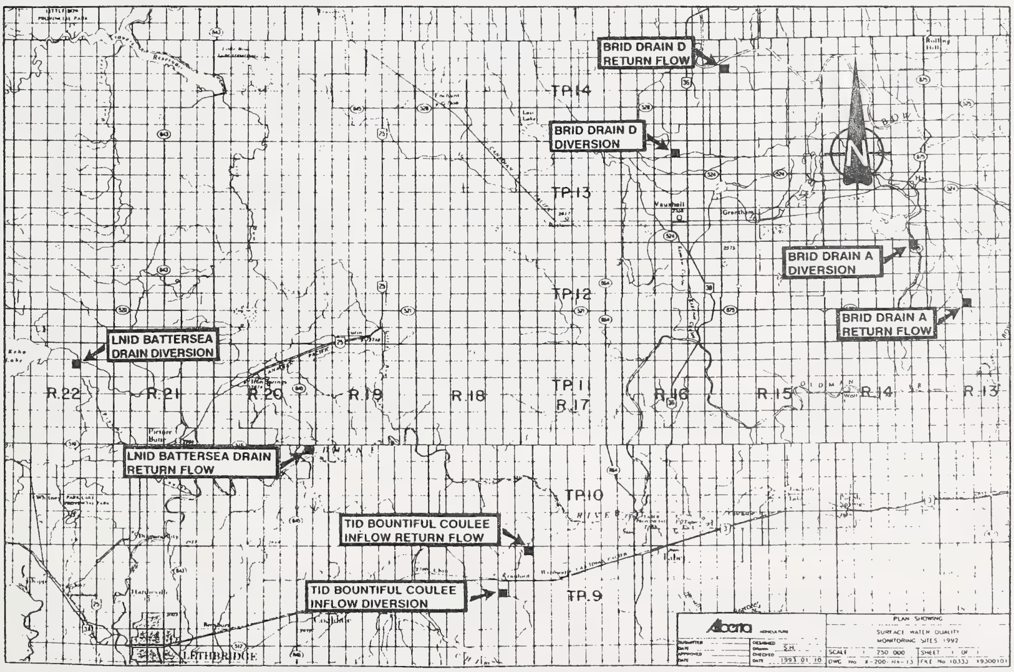

Figure 1. Surface water quality sampling locations.

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absorption spectrometry. Samples collected May 11 were also analyzed for nine herbicides (fenoxaprop-p-ethyl, diclofop-methyl, dicamba, ethalfluralin, bromoxynil, 2,4-D, MCPA, picloram, triallate), using gas chromatography/mass spectrometry (GC/MS) and liquid chromatography/mass spectrometry (LC/MS). Samples collected June 14 were analyzed for 20 herbicides (eight of the above plus metolachlor, flamprop-methyl, tralkoxydim, sethoxydim, trifluralin, dichlorprop, mecoprop, clopyralid, atrazine, metribuzin, hexazinone, bentazon), three insecticides (aldicarb, carbofuran, chlorpyrifos) and two fungicides (carbathiin, propiconazole). Samples collected July 7 from the four return flow streams were analyzed for ten herbicides (fenoxaprop-p-ethyl, diclofop-methyl, dicamba, bromoxynil, 2,4-D, dichlorprop, MCPA, mecoprop, clopyralid).

RESULTS AND DISCUSSION

Most trace element levels were below detection limits throughout most of the monitoring period. Exceptions occurred at all locations on some dates (Table 1, Figures 2 and 3), but consistent trends were not evident. Arsenic was detected at all locations on most dates at levels ranging from 0.0021 to 0.008 mg L^{-1}.

Table 1. Trace element concentrations from water diversion sites and in return flow streams.

Trace Element mg/L[1]	LNID[2] Battersea Drain		TID[2] Bountiful Coulee		BRID[2] Drain "A"		BRID[2] Drain "D"	
	Diversion	Return Flow	Diversion	Return Flow	Diversion	Return Flow	Diversion	Return Flow
AS (0.0003)	< 0.0003 to 0.0034	< 0.0003 to 0.0037	< 0.0003 to 0.008	< 0.0003 to 0.0022	< 0.0003 to 0.0023	< 0.0003 to 0.0029	< 0.003 to 0.0027	< 0.0003 to 0.0021
CD (0.03)	< 0.03 to 0.03	< 0.03 to 0.05	< 0.03 to 0.03	< 0.03 to 0.03	< 0.03 to 0.03	< 0.03 to 0.03	< 0.03 to 0.03	< 0.03 to 0.03
Cu (0.015)	< 0.015 to 0.02	< 0.015 to 0.03	< 0.015 to 0.03	< 0.015 to 0.03	< 0.015 to 0.09	< 0.015 to 0.04	< 0.015 to 0.06	< 0.015 to 0.07
Pb (0.03)	< 0.03 to 0.12	< 0.03 to 0.12	< 0.03 to 0.11	< 0.03 to 0.07	< 0.03 to 0.15	< 0.03 to 0.1	< 0.03 to 0.11	< 0.03 to 0.12
Hg	< 0.001 to 0.0026	< 0.001 to 0.003	< 0.001 to 0.0023	< 0.001 to 0.0026	< 0.001 to 0.0026	< 0.001 to 0.0032	< 0.001 to 0.0038	< 0.001 to 0.002
Se (0.001)	< 0.001 to 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

[1] Detection limits shown in brackets

[2] LNID=Lethbridge Northern Irrigation District
TID =Taber Irrigation District
BRID=Bow River Irrigation District

Cadmium levels of 0.03 mg L^{-1} were detected at all diversion sites and in all return flow streams between July 21 and August 12, and a level of 0.05 mg L^{-1} was found in one return flow stream on July 29. Copper was detected sporadically at all locations between May 19 and October 5 at levels ranging from 0.02 to 0.09 mg L^{-1}. Lead levels of 0.03 to 0.04 mg L^{-1} were present at three diversion sites and in three return flow streams on May 20, and the level in the fourth stream was 0.05 mg L^{-1}. Lead was also found sporadically at all locations between August 12 and October 5 at levels ranging from 0.04 to 0.15 mg L^{-1}. Mercury was detected at all locations at levels of 0.001 to 0.0038 mg L^{-1} between June 14 and

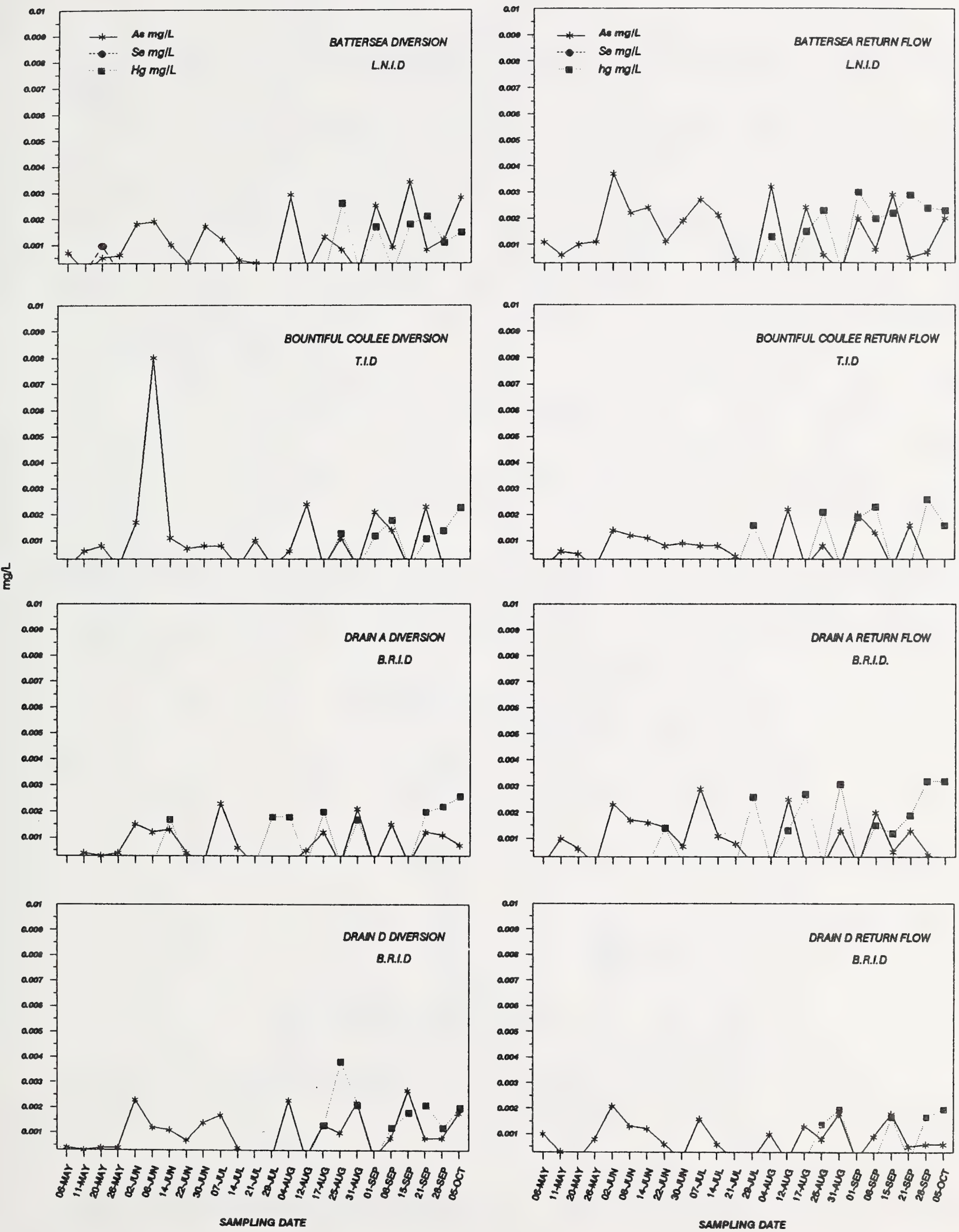

Figure 2. Seasonal arsenic, mercury and selenium levels at water diversion sites and in return flow streams.

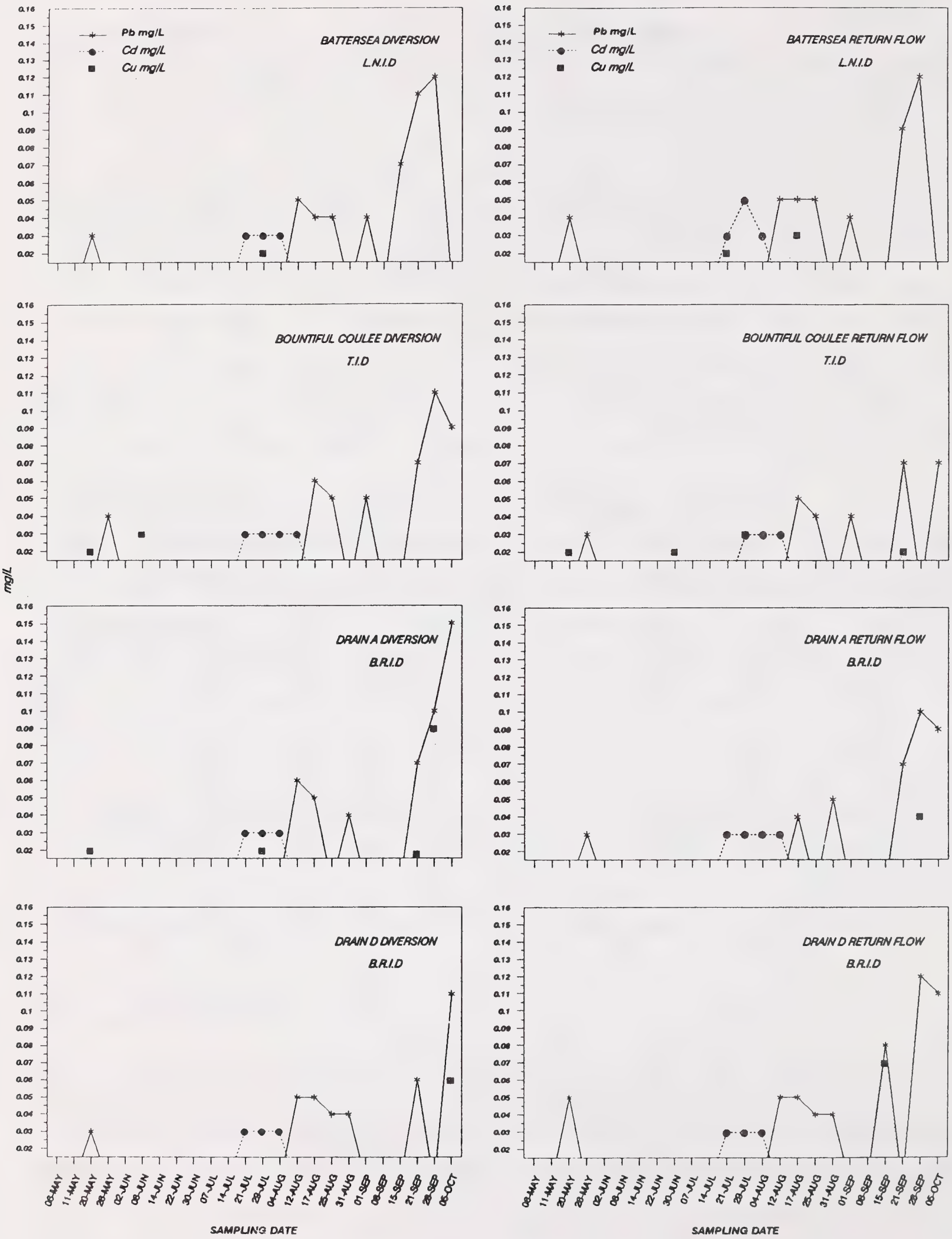

Figure 3. Seasonal cadmium, copper and lead levels at water diversion sites and in return flow streams.

October 5, but was most prevalent during the second half of the irrigation season. Selenium was detected only once at a diversion site on May 20, at a level of 0.001 mg L^{-1}.

Identification of specific sources of trace elements was not part of this monitoring study, and the lack of consistent trends is difficult to explain. Trace elements occur in nature at low concentrations, and their concentrations in different natural environments vary widely (Page et al. 1990). Many trace elements are biologically beneficial at very low concentrations, but become toxic or otherwise detrimental to the health of organisms and plants at low to moderate concentrations. Sources include primarily anthropogenically derived point and nonpoint sources (Anderson 1979; Hem 1985; Mattigod and Page 1983). These include atmospheric pollutants, sewage sludge, soil amendments, irrigation water, pesticides and fertilizers.

A trace of only one herbicide, bromoxynil, was detected at one diversion site on May 11 (Table 2). Detectable, but low, levels of some herbicides were present in all return flow streams and at one diversion site on June 14. MCPA and 2,4-D levels ranged from traces to 4 $\mu g\ L^{-1}$; and traces of dicamba, dichlorprop and bromoxynil were detected. Levels of 2,4-D ranging from 0.38 to 2.8 $\mu g\ L^{-1}$ were found in all four return flow streams and 0.98 $\mu g\ L^{-1}$ of diclofop-methyl was detected in one stream on July 7. Insecticides, fungicides and other herbicides were not detected.

Herbicide presence in return flow streams on June 14 and July 7 suggests a short lag time between crop herbicide applications and herbicide presence in the streams, since water samples were collected during or closely following precipitation events (Figure 4). The source of herbicides at a diversion site

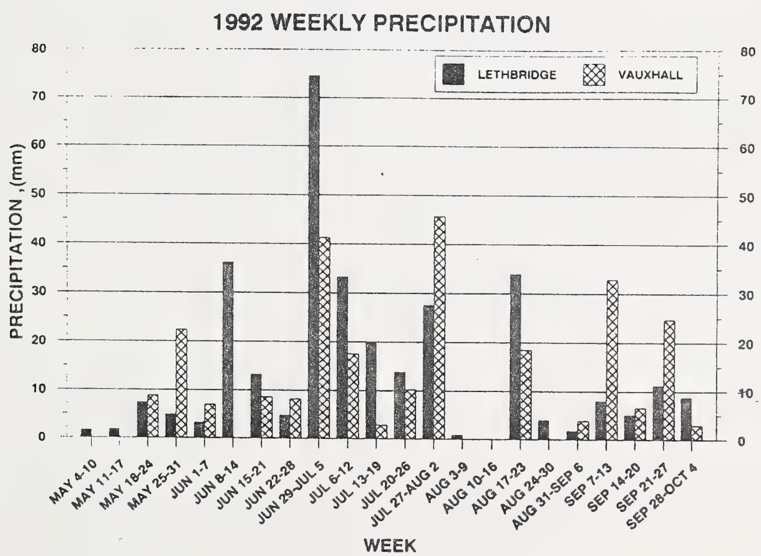

Figure 4. 1992 Seasonal precipitation at Lethbridge and Vauxhall.

on June 14 could have been a herbicide application to control weed growth along canal banks. The St. Mary River Irrigation District is licensed to use dicamba and 2,4-D, the two herbicides which were detected, and the District uses early

Table 2. Pesticide levels from water diversion sites and in return flow streams

Pesticide[1] (ug/L)	LNID[2] Battersea Drain						TID[2] Bountiful Coulee						BRID[2] Drain "A"						BRID[2] Drain "D"					
	Diversion			Return Flow			Diversion			Return Flow			Diversion			Return Flow			Diversion			Return Flow		
	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7	May 11	Jun 14	Jly 7
HERBICIDES																								
Fenoxaprop-p-ethyl (0.15)	ND[3]	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND
Diclofop-methyl (0.1)	ND	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND	ND	ND	–	ND	ND	0.98	ND	ND	–	ND	ND	ND
Metolachlor (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Flamprop-methyl (0.15)	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND
Dicamba (0.15)	ND	ND	–	ND	ND	ND	ND	TR[4]	–	ND	ND	ND	ND	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND
Tralkoxydim (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Sethoxydim (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Ethalfluralin (0.15)	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–
Trifluralin (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Bromoxynil (0.1)	ND	ND	–	ND	TR	ND	TR	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND	ND	ND	–	ND	ND	ND
2,4-D (0.15)	ND	ND	–	ND	0.63	2.8	ND	TR	–	ND	TR	0.38	ND	ND	–	ND	ND	0.41	ND	ND	–	ND	TR	0.59
Dichlorprop (0.1)	–	ND	–	–	TR	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND
MCPA (0.1)	ND	ND	–	ND	4.0	ND	ND	ND	–	ND	ND	ND	ND	ND	–	ND	2.2	ND	ND	ND	–	ND	ND	ND
Mecoprop (0.1)	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND
Clopyralid (0.3)	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND	–	ND	–	–	ND	ND
Picloram (0.2)	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–
Triallate (0.15)	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–	ND	ND	–
Atrazine (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Metribuzin (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Hexazinone (0.4)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Bentazon (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
INSECTICIDES																								
Aldicarb (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Carbofuran (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Chlorpyrifos (0.2)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
FUNGICIDES																								
Carbathiin (0.3)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–
Propiconazole (0.3)	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–	–	ND	–

1 Detection limits shown in brackets
2 LNID=Lethbridge Northern Irrigation District; TID=Taber Irrigation District; BRID=Bow River Irrigation District
3 ND = not detected; a blank indicates samples not collected on this date, or this pesticide was not analyzed for on this date
4 TR = trace (0.1 > ug/L > 0.02)

spring applications to control broadleaf weeds along canal banks (R. Renwick, personal communication). The source of bromoxynil at the same diversion site on May 11 is more difficult to explain, since the District is not licensed to use this herbicide. One possible source could have been a previous year's application on nearby agricultural land, where the herbicide became attached to soil particles, then was carried by wind erosion and subsequently deposited.

CONCLUSIONS

Most trace element levels were well below the Canadian Water Quality guidelines for human and livestock consumption, and irrigation (CCREM 1992). Exceptions included levels of cadmium, lead and mercury detected at some locations on some dates. Cadmium levels of 0.03 mg L^{-1} detected at all four diversion sites and in all four return flow streams between July 21 and August 12, and a level of 0.05 mg L^{-1} detected in one return flow stream on July 29 were above the Canadian Water Quality Guidelines of 0.005 mg L^{-1} for human consumption, 0.02 mg L^{-1} for livestock consumption and 0.01 mg L^{-1} for irrigation. A lead level of 0.05 mg L^{-1}, found in one return flow stream on May 20, equaled the guideline for human consumption. Lead levels of 0.04 to 0.15 mg L^{-1} present between August 12 and October 5 were above the guideline for human consumption at all sites, and above the guideline of 0.1 mg L^{-1} for livestock consumption at all four diversion sites and in three return flow streams. Mercury levels of 0.001 to 0.0038 mg L^{-1} detected between June 14 and October 5 were above the guideline for human consumption of 0.001 mg L^{-1} at all sites, and above the guideline of 0.003 mg L^{-1} for livestock consumption at one diversion site and in two return flow streams. The maximum levels of arsenic, cadmium and lead were higher than those reported previously for southern Alberta (Bolseng 1991; Bolseng 1992). The maximum level of selenium was lower than reported previously.

Bromoxynil, 2,4-D, dicamba and diclofop-methyl levels were well below the Canadian Water Quality Guidelines for human and livestock consumption, and irrigation. Dichlorprop and MCPA levels were also very low, although water quality guidelines are not presently available for these compounds.

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LONG-TERM WATER-LEVEL TRENDS IN THE BOW RIVER AND TABER IRRIGATION DISTRICTS

S. Joan Rodvang[1]

INTRODUCTION

Irrigation development has the potential to cause a water-level rise due to increased recharge. Water-levels were monitored periodically over the past 14 years in two irrigated areas of southern Alberta to check for trends.

METHODS

Groundwater investigations were conducted at study areas in the Bow River (BRID) and Taber (TID) Irrigation Districts between 1978 and 1981 by Alberta Agriculture (Hendry 1981; Hendry et al. 1982). The BRID study area is located in Township 14, Range 15, and the TID study area is located in Township 11, Range 16.

Water-table wells were installed at 31 locations in the BRID and 45 locations in the TID. Piezometers were also installed at most sites, at depths ranging from three to 50 metres below ground.

Water-levels were monitored monthly between 1978 and 1980 in both study areas. All piezometers which had not been destroyed were flushed and purged in 1990 to remove contamination. Water-levels were re-measured on three occasions between 1990 and 1992 (Rodvang 1993a). The level of the water-table is measured in water-table wells, while piezometers are used to record the water pressure, or hydraulic head, in specific geologic units.

DESCRIPTION OF THE STUDY AREAS

Irrigation Development

The study area in the BRID was developed for surface irrigation between 1920 and 1940. Wheel moves were introduced during the 1960's and 1970's, followed by centre pivots during the 1980's.

Surface irrigation was introduced at the southern end of the TID study area in 1952. The remaining area was not developed until 1976, when centre pivots were put into operation over most of the study area.

Geology and Climate

The TID study area is underlain by 40 m of till, which is visually unweathered below 12 m. Sand layers are very common at the surface and buried in the till. A pre-glacial river deposit of sand and gravel which is about four m thick occurs between the till and bedrock. Bedrock consists of soft Cretaceous sandstone and shale. The water table occurs in shallow sand and till at an average depth of 2.8 metres (m).

Geology at the BRID study area consists of about 15 to 45 m of weathered till over soft Cretaceous sandstone and shale. Surficial and buried sand lenses and layers are common, but less predominant than in the TID study area. The water table occurs at an average depth of 2.3 m.

Between May and October, the study areas receive about 22 cm of

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precipitation, and evaporative losses are over 75 cm. About 85 cm of water is delivered to the study area per year (Rapp and van Schaik 1972).

RESULTS AND DISCUSSION

The limited water-level data recorded since 1990 indicates water levels at many sites changed significantly between 1978 and 1992. Trends were highly variable because of variations in land use and local topography between sites. The trends were subdivided into five major types, as summarized for shallow and deep piezometers in Table 1. An example of each type of trend is shown in Figure 1.

Declining Water Levels

Water levels were either constant or declined in most piezometers located on non-irrigated sites, whereas water levels declined at only three irrigated sites (Table 1).

Gradually declining water levels were probably the result of changes in land use, or the drought which persisted throughout most of the 1980's. Water levels would be expected to decline most significantly in recharge areas. The cause of the significant drop in water level between 1980 and 1990 in buried sand at site 2989 is difficult to assess, since there is a ten-year data-gap between readings.

Water Level Increases in the TID

Gradually rising water levels may be caused by a slow recovery to equilibrium. Piezometric levels in formations with a very low hydraulic conductivity or a low storage capacity require long periods of time to reach equilibrium. Piezometers which are thought to exhibit gradually rising water-levels due to slow response times have been removed from the summary in Table 1, and are discussed by Rodvang (1993b).

The gradually rising trends summarized in Table 1 may be the result of increased groundwater recharge. Most of the piezometers were completed in shallow till and sand deposits, which are not expected to exhibit the drawn out recoveries of deeper deposits.

Increased groundwater recharge is probably the cause of water-level rises between 1981 and 1990 in the four surficial irrigated sites in the TID (Table 1). The jumps occurred in shallow sand and till deposits at less than ten metres depth, and were of the same magnitude as gradually rising water-levels shown by other sites in the TID.

If it is assumed that water levels rose due to increased recharge, then increased recharge occurred at over half the sites in the TID, and at only one site in the BRID. Most of the TID study area was developed for irrigation only one to three years before the initial investigation, while the BRID was developed much earlier. Therefore, water levels in the TID may have been equilibrating to new levels during the investigation, as a result of irrigation development.

Water-Level Rises in the BRID

In cases where water levels were constant, and then rose some time between 1980 and 1990, the cause may be either increased recharge or piezometric error.

Water levels during the initial monitoring period may have been artificially low due to smeared boreholes or clogged screens (Rodvang 1993b). Although 1990 readings were recorded before the second development procedure, natural groundwater flow during the ten year interval may gradually have reduced borehole disturbance. If borehole disturbance was responsible for the water-level jumps, water levels would be expected to rise after piezometer development in 1990, when

Table 1. Summary of Water-Level Trends (1978 to 1992)

		Gradual Decline Throughout Monitoring Period			Constant, With Drop Between 1980 and 1990			Constant Throughout Entire Monitoring Period	Gradual Rise Throughout Monitoring Period			Constant, With Jump Between 1980 and 1990		
Category	Total Number of Sites	No. of Sites	[z] Range (m)	Average (m)	No. of Sites	Range (m)	Average (m)	No. of Sites	No. of Sites	Range (m)	Average (m)	No. of Sites	Range (m)	Average (m)
BRID - non-irrigated	3	2	0.45-1.81	1.13	1	---	2.32	1	1	---	0.2	1	---	0.49
TID - non-irrigated	2	1	0.6	0.6	0	---	---	1	0	---	---	0	---	---
BRID -irrigated surficial (<20 m deep)	8	1	1.6-3.7	2.65	2	0.72-0.75	0.73	5	1	0.21	0.21	0	---	---
TID - irrigated surficial (<30 m deep)	15	0	---	---	0	---	---	3	8	0.2-1.0	0.5	4	0.5-0.66	0.59
BRID - irrigated bedrock and deep till (>20 m deep)	6	0	---	---	0	---	---	0	0	---	---	6	0.31-1.40	0.93
TID - irrigated bedrock and pre-glacial gravel (>30 m deep)	2	0	---	---	0	---	---	2	0	---	---	0	---	---

[z] range and average refer to the net change in water level

Note: For some categories the number of sites showing trends is greater than the total number of sites. This is because some sites show different trends at different depths.

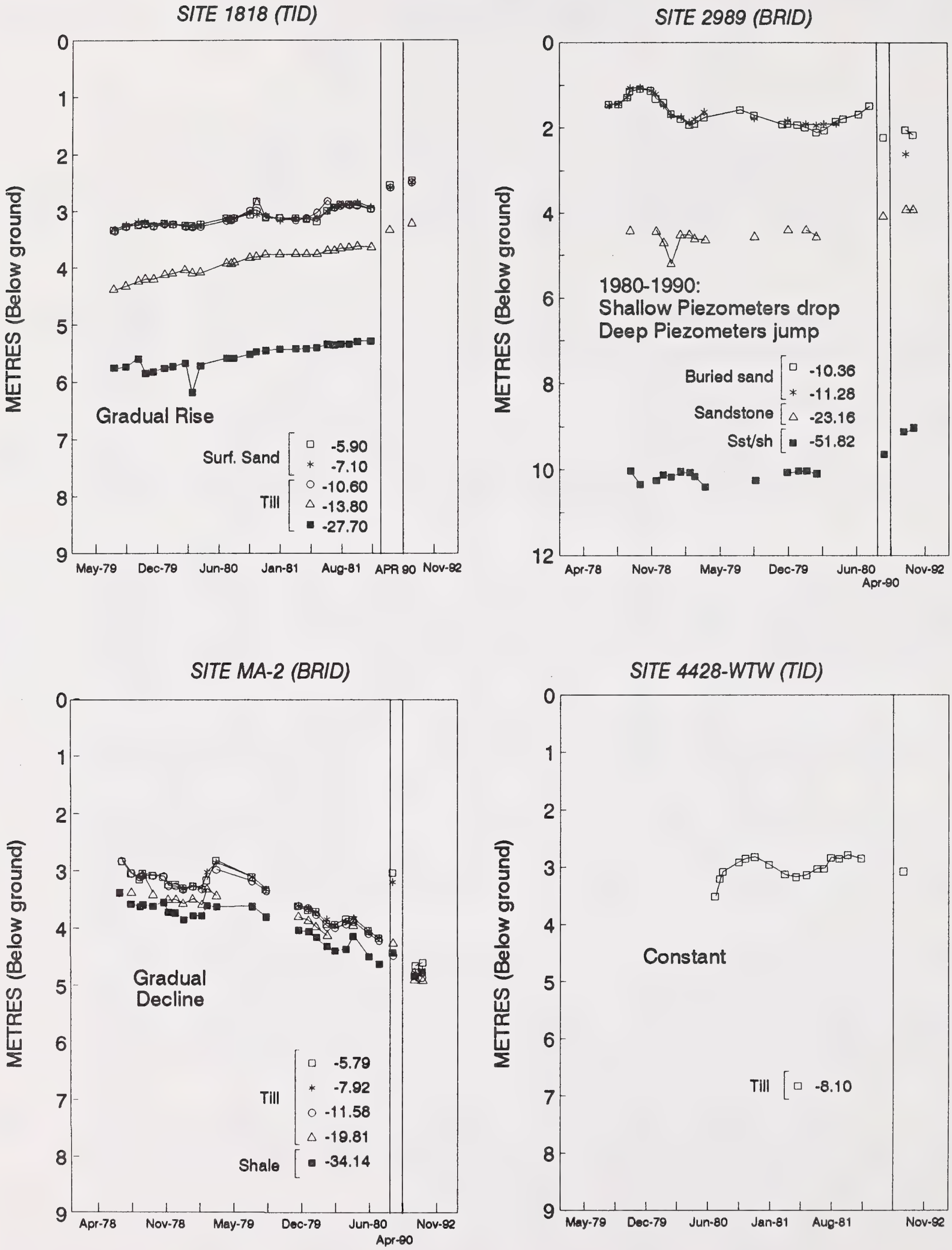

Figure 1. Examples of water-level trends (1978 to 1992).

substantial contamination was removed from many piezometers. However, 1992 readings were similar to 1990 readings in most piezometers.

Sudden jumps in water level in the Milk River basin were caused by piezometer development. This suggests that the water-level rises in the BRID may be the result of piezometric error.

Alternatively, irrigation may be causing groundwater to build up in the bedrock at the BRID. The relatively uniform amount of the water-level increase, and the fact that it occurs in all deep piezometers below irrigated sites, may indicate that this is occurring. In their study in the BRID, Rapp and van Schaik (1971) found that water-tables almost always rose to the surface immediately following an irrigation event, followed by a recession due to consumptive use and deep drainage. Deep drainage following irrigation events may be contributing to a groundwater build-up at depth in the BRID.

<u>Implications of Long-Term Water-Level Trends in the BRID and TID</u>

Water tables can rise due to canal seepage and over-irrigation, particularly in areas where plant growth is poor, or where drainage is restricted due to texture, topography or high sodicity levels. Water build-up is more likely under surface, as compared to pivot irrigation methods, due to uneven water application using the former method.

Water-table levels in the BRID were monitored by Agriculture Canada between 1958 and 1985. Beke et al. (1991) found that water-tables rose at about half the sites, and that water-tables were more likely to rise when till was within 1.5 m of ground surface. Rapp and van Schaik (1972) found that mean water-table heights rose by 0.4 to 0.7 m during the monitoring period. They attributed the rise to an increase in both irrigated area and natural precipitation during the monitoring period.

Soil-salinity problems are more likely to develop on lands with water-tables less than 0.9 to 1.5 m below ground (Sommerfeldt et al. 1988).Water levels in the BRID and TID are near this critical depth. The current investigation suggests that shallow water levels in the BRID have stabilized at most sites, while shallow water levels in the TID may still be rising.

Permanent water-tables in a non-irrigated study area in the Milk River Basin averaged about 15 m deep, although shallow perched water-tables were common (Rodvang 1993c). Water levels are affected by many factors in addition to irrigation development. However, the large difference in water tables at sites which are relatively similar in climate and geology, underlines the importance of obtaining background water level information before irrigation development, and continuing to monitor water-levels in the long-term.

CONCLUSIONS AND RECOMMENDATIONS

Shallow water levels below five non-irrigated sites in the TID and BRID either dropped, or were constant throughout the 1978 to 1992 period.

Water levels in surficial deposits at most irrigated sites in the TID rose by about 0.5 m between 1978 and 1992. Shallow water levels probably rose in response to irrigation development, which occurred over most of the study area in 1976. Water levels in deep piezometers were constant.

Water levels in surficial deposits at irrigated sites in the BRID rose slightly at only one site, and were constant or dropped at all other sites. Surficial water-level trends in the BRID suggest that if water-levels rose in response to irrigation development during the 1920's, they have now stabilized.

Water levels in bedrock and till deposits at depths below 20 m rose by 0.3 to 1.4 m between 1980 and 1990 at all irrigated sites in the BRID. Evidence from

the Milk River basin indicates that the increases may be an anomaly imposed by the piezometers. Conversely, the uniformity of the rise suggests that groundwater may be building up in deeper deposits in the BRID, possibly as a result of deep drainage.

Water levels in the BRID and TID are near the critical depth for development of soil salinity problems. Water levels should be regularly monitored at these sites over the long-term.

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HYDROGEOLOGICAL STUDY OF THE LETHBRIDGE AQUIFER

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INTRODUCTION

Pre-glacial river valleys are important groundwater aquifers in Alberta. The sand and gravel of the original valleys were covered by glacial drift at the end of the Pleistocene. Where buried valleys are intersected by recent streams, their ground water drains into the recent valleys. As a result, flow patterns in pre-glacial gravel aquifers are very complex, with confined, unconfined, and dry conditions all occurring at different locations. The pre-glacial river valley between Magrath and Taber in southern Alberta is known as the Lethbridge Aquifer.

The goal of this study was to characterize the hydrogeology of the Lethbridge Aquifer, with emphasis on the delineation of flow paths and the evolution of ground water chemistry. Study of the over-lying till was an important part of the project.

METHODS

Existing data on the Lethbridge Aquifer was compiled to define the geometry and approximate flow patterns within the aquifer and over-lying till.

Thirteen piezometers (1.5" I.D.) were installed between July 1991 and July 1992 (Figure 1). Bail tests were conducted to determine hydraulic conductivity using the Hvorsev method (Hvorslev 1951). Samples for geochemical analyses were collected from piezometers and from several farms wells screened within the aquifer. Temperature, pH, and dissolved oxygen were measured in the field. Samples were analyzed by the Alberta Agriculture laboratory for major ions, total iron and nitrogen species.

Additional sampling was conducted to determine redox conditions in the aquifer. Concentrations of sulfide (S^{2-}) were determined in the laboratory after precipitation with zinc acetate in the field. Filtered and acidified samples were transported to the laboratory for determination of arsenic species. They were first analyzed for As(III), then reduced and re-analyzed for the concentration of As(III). The concentration of As(V) was determined as the difference between As(III) concentrations before and after reduction.

Ground water was also analyzed for oxygen-18, deuterium, and sulfate isotopes at the University of Waterloo. Concentrations of tritium were determined at the Isotopic Laboratory of Alberta Environment at Vegreville.

The groundwater chemistry data (including seven major ions and all geologic units) was interpreted using two multivariate statistical procedures: the Cluster Analyses (CA) and the Principal Component Analyses (PCA). The CA separates samples into groups on the basis of the similarity between them.The PCA is based on a calculation of principal components that correspond to different hydrogeochemical processes and groups.

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RESULTS AND DISCUSSION

Geometry of Till and Bedrock

The thickness of Quaternary sediments in the study area increases towards the north, from less than ten metres between Stirling Lake and the Milk River Ridge, to 20 to 25 m south of Lethbridge, to 85 m at Lethbridge. The thickness of till between Lethbridge and Taber is about 50 metres (Figure 1).

The Foremost, Oldman and Bearpaw Formations are all in direct contact with the Lethbridge Aquifer. The Foremost Formation underlies the Lethbridge Aquifer in the eastern part of the study area. It is comprised of shale and sandstone layers with occasional coal seams. The sandier Oldman Formation, which contains an exploited coal seam at the top, underlies the western part of the aquifer. The Bearpaw Formation, which is mainly shale, underlies the southern part of the aquifer, close to the Milk River Ridge. All three bedrock units were exposed between the Upper Cretaceous and the Oligocene, with the result that weathered layers of variable thickness occur at their tops.

There are two major orthogonal joint sets in southern Alberta (Babcock, 1973). The lineaments and jointing in coal seams are consistent with System One, with a strike of about 65 degrees, (and an orthogonal set at 155 degrees). System 2 is less significant, with a strike of about 5 degrees (and an orthogonal set at 95 degrees).

Geometry of the Lethbridge Aquifer

The Saskatchewan Gravels in the Lethbridge Aquifer are fluvial sediments, composed mainly of quartzite, Crowsnest volcanics, sandstone and shale, with a variable amount of limestone (Stalker, 1968). Particle-size ranges from 40 to 150 mm. The gravels were deposited between the Oligocene and the beginning of the Laurentide glaciation (Stalker, 1968).

The Lethbridge Aquifer south of Lethbridge is composed of an eastern branch called the Stirling branch, and a western branch called the Whoop-Up branch. The two branches join north of Raymond (Figure 1). At the McNally site (immediately south of Lethbridge), the preglacial valley begins to curve towards the northeast, with a dip towards Coaldale. The aquifer reaches its maximum thickness of more than nine metres at Lethbridge. It is about one to three metres thick south of Lethbridge, and six metres thick northeast of Lethbridge.

Horizontal hydraulic gradients within the aquifer indicate that groundwater flow is generally towards the north. The average horizontal hydraulic gradient of the base of the aquifer south of Lethbridge is 0.004. The valley widens and flattens between the McNally Site and Lethbridge, for an average horizontal hydraulic gradient of about 0.002 at its base. The deepest part of the preglacial valley is located north of Chin Coulee.

Hydraulic Conductivity of Till and Bedrock

The hydraulic conductivity of the bedrock units varies with the degree of weathering of their upper surfaces, and the presence of fractures. Values vary from 10^{-8} m s^{-1} for shallow parts of the Oldman and Foremost Formations, to 10^{-10} m s^{-1} for the Bearpaw Formation.

Hydraulic conductivity values for till were based on bail tests, and the damping oscillation theory (Keller et al. 1989) applied to hydrographs from piezometers completed in till. Results indicate that the hydraulic conductivity of the weathered till (10^{-8} to 10^{-10} m s^{-1}) was about two orders of magnitude higher than that of the non-weathered till (10^{-10} to 10^{-11} m s^{-1}). The higher hydraulic conductivity of the oxidized till is due to the presence of fractures.

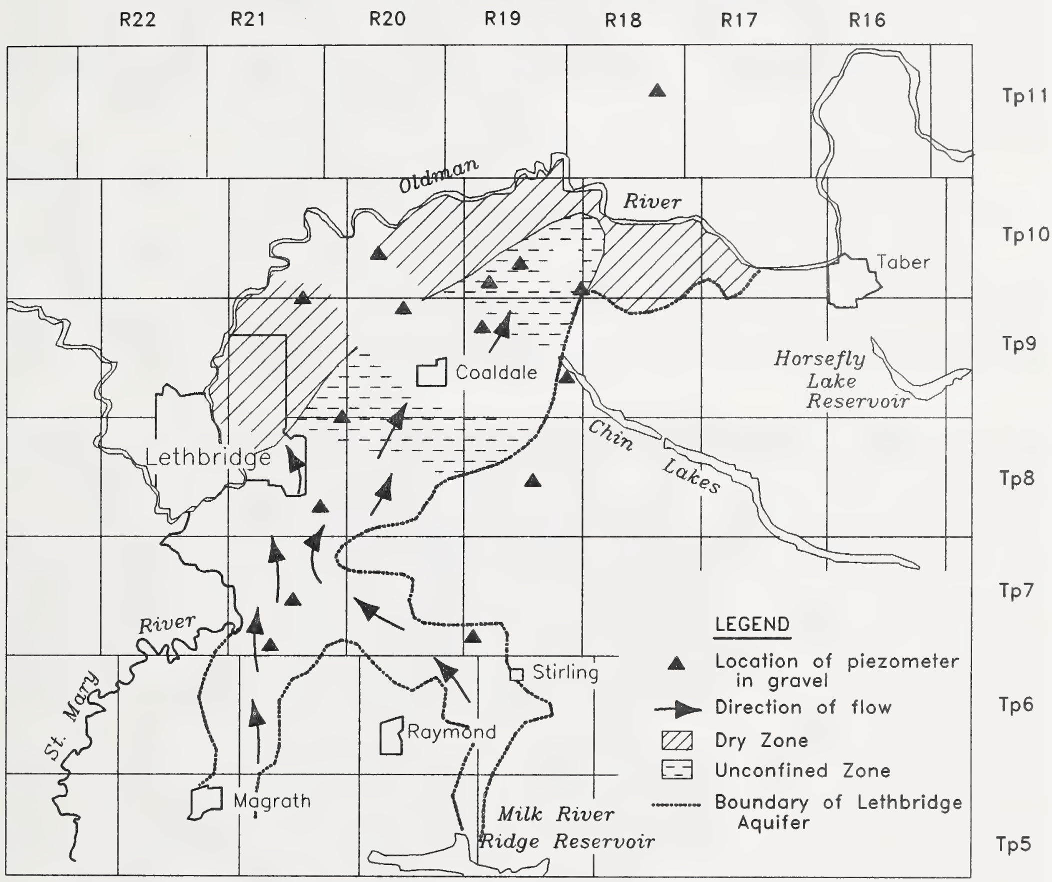

Figure 1. Geometry and flow in the Lethbridge Aquifer.

Hydraulic Conductivity of the Lethbridge Aquifer

Hydraulic conductivity within the Lethbridge Aquifer varies over four orders of magnitude. The large range in hydraulic conductivity is imposed by the extremely heterogeneous fluvial sedimentary environment, and the presence of post-sedimentary cementation of gravels in some areas.

The analysis of pumping tests and bail tests in the Lethbridge Aquifer indicated hydraulic conductivity values on the order of 10^{-6} to 10^{-7} m s^{-1}. Hydraulic conductivities determined from the specific capacity of farmer's wells ranged from 10^{-3} to 10^{-6} m s^{-1}. The latter values were probably overestimated due to uncertainties in drilling reports. Nevertheless, hydraulic conductivity northeast of Lethbridge may be about two orders of magnitude higher than south of Lethbridge.

Flow Patterns in Till and Bedrock

Flow in the till is mainly vertical, with extremely low fluxes in the unoxidized zone (less than six metres per ten thousand years).

The Saskatchewan gravels act as a drain due to their high permeability. Flow within bedrock units which are not overlain by the Saskatchewan Gravels are mainly towards the Lethbridge Aquifer. In areas where bedrock is directly overlain by Saskatchewan Gravels, groundwater probably flows into the underlying weathered bedrock, and re-enters the aquifer at topographic depressions in the base of the aquifer.

Flow Patterns in the Lethbridge Aquifer

Most recharge to the Lethbridge Aquifer occurs in the Milk River Ridge area, where the till is very thin. Several flowing artesian wells occur south of Stirling Lake because of the high altitude of the recharge area.

The Lethbridge Aquifer is confined south of Lethbridge, but long-term hydraulic head data in an observation well completed in the gravel at the McNally site (immediately southeast of Lethbridge) indicate that groundwater depletion is occurring in the Lethbridge area. Hydraulic head at the site declined throughout the 1970's and early 1980's. The regression equation for the decline was hydraulic head (metres) = 860 - 0.167 t (years). Hydraulic head declines steeply to the north of this site, and the aquifer becomes unconfined, and even dry below Lethbridge.

The steep decline in hydraulic head between the McNally site and Lethbridge is related to the draining effect of mining works below Lethbridge. Coal mining began in 1872 in the Lethbridge area. The mining caused subsidence, which increased the permeability of the top of the bedrock due to upward void migration (Sladen and Joshi 1988). This promoted drainage of ground water from the Lethbridge Aquifer into the mining works.

The unconfined zone has spread to the area northeast of Coaldale, although a perched water-table occurs in till. An analytical groundwater solution (Sracek, 1993) indicates that the spreading of the dewatered zone could not yet have reached Coaldale. Therefore, a residual potentiometric mound probably occurs in the Coaldale area. Before mining development, some groundwater drained from the aquifer into the river at Lethbridge. However, the main dip of the aquifer is towards Coaldale, so drainage into the river before mining development was quite minor.

The aquifer is also unconfined in the area north of Chin Coulee. This is due to drainage of ground water from the aquifer into the recent Oldman River valley north of Chin Coulee (Figure 1).

Geochemistry and Isotope Content in the Till and Bedrock

The climate became extremely warm and dry between about 10,000 and 3,000 years ago, during what is known as the Altithermal Period. The warm and dry conditions caused the upper till to become unsaturated, with the result that major-ion concentrations increased due to the oxidation of reduced sulfur and pyrite, carbonate and gypsum dissolution, and cation exchange (Hendry et al. 1986).

Major-ions released in the oxidized till are transported from the oxidized to the unoxidized zone by diffusion and advection. Ground water in till evolves from Na-Ca-Mg-SO_4-HCO_3 type in the oxidized till, to Na-HCO_3-SO_4 type water in the unoxidized till. Extremely high concentrations of nitrate (up to 1900 mg/L) occur in oxidized till at the McNally site, but denitrification reduces nitrate concentrations to below the limit of detection at the top of unoxidized till. The PCO_2 values in the oxidized till increase with depth, probably due to microbial activity and denitrification.

Tritium is transported downwards by advection and diffusion, but it does not penetrate below 15 m depth. Ground water in the shallow oxidized till is enriched in oxygen-18 and deuterium due to evaporation. Both isotopes decrease with depth in the till. Oxygen-18 and deuterium data correspond to late winter-early spring precipitation.

Hydrogeochemical information on the bedrock is very limited. With the exception of SO_4^{2-}, major-ion concentrations generally increase with depth.

Hydrochemistry, Isotopic and Redox Conditions in the Lethbridge Aquifer

Ground water in the Lethbridge Aquifer is supersaturated with respect to calcite and dolomite, and undersaturated with respect to gypsum. Calculated PCO_2 concentrations are about 10^{-2} bar, with the highest PCO_2 value ($10^{-1.65}$ bar) occurring in the unconfined zone east of Lethbridge. This suggests that CO_2 may be the main gas in the unsaturated zone between the base of the till and the base of the aquifer.

The aquifer is slightly reducing, with Eh values calculated on the basis of As(111)/AS(V) couples ranging from -40 to -150 mV. At the pH range of the aquifer, an eH value of less than -180 mV is necessary before sulfate reduction can occur. Nevertheless, sulfate isotopic data indicate that limited sulfate reduction is occurring in till and bedrock, and at several sites in the Lethbridge Aquifer. The sample which is most enriched in ^{34}S is from a farm well northeast of Coaldale (Figure 1) with a value of +26.82 per mil. Sulfate in the Lethbridge Aquifer has the same isotopic fingerprint as the unoxidized till, which suggests that chemical evolution in the two units is closely related.

Tritium concentrations in the Lethbridge Aquifer are generally less than one tritium unit, even south of Stirling Lake, where the till is less than 10 m thick. Downward diffusion is probably inhibited by upward advective gradients in the till in this area.

South of Lethbridge, ground water in the Whoop-Up branch is of a Na-Ca-SO_4-HCO_3 type, with an electrical conductivity (EC) of about 1.6 mS/cm. Ground water within the Stirling branch is of Na-SO_4-HCO_3 type, with an EC of up to 3.5 mS/cm, and higher concentrations of all major ions. Ground water in the Stirling branch is slightly enriched in oxygen-18 and deuterium compared with the Whoop-Up branch. This suggests that the Stirling Branch receives recharge water from the (partially evaporated) Milk River Ridge Reservoir, whereas the Whoop-Up branch does not. Geochemical differences between the branches still exist immediately southeast of Lethbridge, with indicates that the low permeability barrier does not allow mixing of ground water between the branches even after their apparent confluence.

Major-ion concentrations decrease slightly between Stirling Lake and Lethbridge. The decrease is probably the result of dispersion in the anastomosing gravel channels, and not the result of hydrogeochemical processes in the aquifer.

In the unconfined zone northeast of Coaldale, about 95% of the sulfate disappears, and ground water changes to a Na-HCO_3 type. Sulfate reduction alone cannot account for these changes. Mixing calculations based on Cl^- concentrations indicate a significant contribution of ground water from an unknown source, probably a buried sand channel in till.

Major-ion concentrations then increase again towards seepage faces north of Chin Coulee. The increase is probably partly the result of evaporation, but computer simulations indicate that another process must be occurring as well.

<u>Multi-variate Statistical Analysis of Groundwater Chemistry</u>

Cluster Analysis indicated that the geochemistry of the oxidized till was most different from all other geologic units. Many samples from the unoxidized till and the Lethbridge Aquifer occurred in the same cluster, suggesting that the unoxidized till exerts a major control on the chemistry in the Lethbridge Aquifer.

Principle Component analysis (PCA) yielded two main principal components: 1) groundwater with a high loading of Ca^{+2}, Mg^{+2}, and SO_4^{2-}, corresponding to typical oxidized till water; and 2) groundwater with a high loading of Na^+ and HCO_3^-, corresponding to typical unoxidized till water. The PCA indicated that groundwater chemistry in the Lethbridge Aquifer is controlled by two major processes: 1) the advective and diffusive transport of major-ions and tritium through the oxidized and unoxidized till to the aquifer; and 2) the mixing of groundwater from the Lethbridge Aquifer with that from shallow bedrock.

CONCLUSIONS

Before glaciation, the river system which is now the Lethbridge Aquifer flowed north from the Milk River Ridge towards Coaldale and Taber. After it was covered with glacial drift, it became an aquifer, with recharge occurring through the thin till in the Milk River Ridge area, and flow towards the north. Flow patterns and groundwater chemistry in the Lethbridge Aquifer have evolved due to three major changes which occurred in southern Alberta since the last glacier withdrew about 10,000 years ago.

Oxidation of till during the altithermal period caused major-ion concentrations to increase significantly in weathered till. Recharge through the till, which occurred mainly through thin till in the Milk River Ridge area, carried elevated major-ion concentrations into the Lethbridge Aquifer.

The second important change following glaciation was the incision of the Oldman River into the prairie upland. This incision occurred about 2,500 to 2,000 years ago, with the result that groundwater from the Lethbridge Aquifer drained into the recent Oldman River valley. This drainage produced an unconfined zone in the aquifer north of Chin Coulee, and a smaller unconfined zone in the Lethbridge area.

The third major change was coal mining development in Lethbridge in 1872, which resulted in drainage from the Lethbridge Aquifer into the coal mining works. This drainage resulted in an unconfined zone east and south of the mining works.

Geochemical and flow conditions in the Lethbridge Aquifer are still in a transient state. The dewatered zones caused by drainage into mining works and the recent river valley continue to spread upgradient. Elevated major-ion concentrations from the till continue to be transported into the aquifer.

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THE EFFECT OF INSTALLATION AND DEVELOPMENT TECHNIQUES ON ROUTINELY MEASURED GROUNDWATER PARAMETERS

S. Joan Rodvang[1]

INTRODUCTION

Methods for installation and development of groundwater devices continue to evolve. Recent experience indicates the necessity for following correct development techniques, and suggests the need for the development of a new installation technique for till.

METHODS

Groundwater devices have been installed by the Land Evaluation and Reclamation Branch at many locations in the last 20 years.All piezometers were installed using a mud-rotary drilling technique. Following installation, piezometers were developed by flushing with surface water to remove soil particles from the screens. Piezometers were purged of water one or more times before samples were collected. Bail tests were conducted to measure hydraulic conductivity (Hvorslev 1951).

BRID and TID

Hendry (1981) and Hendry et al. (1982) determined major-ion concentrations at 159 piezometers in study areas in the Bow River (BRID) and Taber Irrigation Districts (TID). During 1990, 77 piezometers were re-sampled (Rodvang 1993a). Several piezometers were contaminated, usually by mice or surface soil after damage to the above-ground portion of the piezometer. Contaminated installations were flushed with water and then bailed. All piezometers were bailed to dryness twice before sampling with a bailer.

Water-levels were monitored monthly between 1978 and 1980 in the BRID and TID study areas. All piezometers which had not been destroyed were re-monitored on three occasions between 1990 and 1992 (Rodvang 1993b). The 1990-water-level readings were recorded before the 1990 flushing and purging operation.

Milk River

Piezometers were installed in the Milk River Basin in 1988 (Rodvang 1993c), to expand on the original Milk River study area (Robertson 1988). During 1991 many of the new piezometers were flushed again to remove silt and mud which was clogging screens. Piezometers were then bailed at least four times, until pH, temperature and electrical conductivity stabilized. Hydraulic conductivity was measured using bail tests before and after the second flushing. Five piezometers from the original study area of Robertson (1988) were also re-tested for hydraulic conductivity. The five piezometers were all completed in alluvium and the Vergille sandstone.

Major ion chemistry and tritium content were determined before and after the second flushing in post-1988 piezometers. Tritium is a radioactive isotope of hydrogen which is used to indicate water which entered the groundwater system after 1953.

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WID

Groundwater samples were collected on two occasions in the study area located in the Western Irrigation District (WID) (Rodvang 1989). Before the second set of samples was collected, piezometers were bailed at least four times, until pH, electrical conductivity and temperature stabilized.

Lethbridge Aquifer

Groundwater samples collected by Scracek (1993) were dated using tritium, and compared to expected ages based on groundwater flow parameters.

RESULTS

BRID and TID

A comparison of groundwater chemistry from samples collected in 1990 with those collected in 1979-80 at the BRID and TID indicated that most samples were very similar. However, some 1990 samples exhibited significantly lower major-ion concentrations.

Hydraulic conductivity values measured on piezometers in weathered till ranged from 10^{-6} to 10^{-9} m s^{-1}, with an average value of 7 x 10^{-8} m s^{-1}.

Water levels rose between 1978 and 1992 at many sites in the BRID and TID. Although some of these increases are probably the result of increased recharge (Rodvang 1993b), others probably reflect piezometric error. Piezometric levels in buried sand and till at site 1813 in the TID rose steadily by over 10 m between 1979 and 1992. Piezometric levels in bedrock were constant in the BRID and TID between 1978 and 1981. However, the water-level at site 1811 in the TID rose by 12 m between the 1981 and 1990 readings. Over the same time interval, water levels in bedrock and deep till in the BRID rose by 0.3 to 1.4 m at all sites.

Milk River Basin

Major-ion concentrations increased significantly, and tritium levels decreased significantly, between the first and second sampling events in the Milk River study area.

Post-1988 piezometers completed in the Milk River sandstone exhibited hydraulic conductivity values which were generally one order of magnitude higher after the flushing and purging operation of 1991 than they were initially. The average hydraulic conductivity of the Milk River sandstone rose from 3 x 10^{-6} ms^{-1} in 1989 tests, to 6 x 10^{-5} m s^{-1} in 1991 tests. Hydraulic conductivity values measured on pre-1988 piezometers completed in the Milk River Sandstone by Robertson (1988) were also one order of magnitude lower than values measured on the same piezometers in 1992.

Hydraulic conductivity values reported by Robertson (1988) for two piezometers completed in alluvium were one and three orders of magnitude lower than values obtained on the same piezometers after bailing them in 1991.

Water-levels rose gradually by up to one metre between 1988 and 1992 in many piezometers completed in the Milk River sandstone. Water levels in some of these piezometers also exhibited a slight jump following piezometric development in 1991.

WID

Major ion concentrations in most piezometers increased significantly between the first and second sampling rounds at the WID.

Lethbridge Aquifer

Scracek (1993) found many samples contained more tritium (indicating a higher content of water which recharged after 1953) than expected from groundwater flow parameters.

DISCUSSION

Dilution of Groundwater Chemistry and Isotopic Content

Groundwater chemistry can be diluted by both drilling fluid and surface water added during flushing.The increase in major-ion concentrations and the decrease in tritium at many piezometers following extensive purging indicates that they were not adequately bailed before initial samples were collected. Scracek (1993) did not flush piezometers before sampling, but bailed them extensively. This indicates that it is very difficult to remove even the water added during mud-rotary drilling.

Measurement of Hydraulic Conductivity from Piezometers in Till

McKay (1992) used a wide variety of methods to show that the bulk hydraulic conductivity of fractured till in southwestern Ontario is about 2×10^{-7} m s^{-1}. D'Astous et al. (1991) measured values of 10^{-9} to 10^{-11} m s^{-1} from augered piezometers at the same site.

Two factors cause the hydraulic conductivity of till measured from piezometers to be lower than the true bulk hydraulic conductivity. Firstly, most of the permeability in till is imparted by vertical fractures, which have a relatively low probability of being intersected by vertical boreholes.

If a range of hydraulic conductivity values are measured from piezometers completed in till, the maximum value is probably most representive of bulk hydraulic conductivity (McKay 1991). Therefore, fractured till in southern Alberta probably has a bulk hydraulic conductivity of about 10^{-6} m s^{-1}. The conductivity may be higher than that of the till in southwestern Ontario because it has a higher sand content.

A second factor which often results in lowered hydraulic conductivity is the smearing of clay particles around the borehole wall during drilling. Borehole smear reduced hydraulic conductivity by about one order of magnitude at the above site in southwestern Ontario (D'Astous et al. 1991).

Borehole smear has not previously been noted in tills in Alberta, but it may lower measured hydraulic conductivity to some degree. D'Astous et al. (1991) found that a double shelby-tube coring device effectively reamed the smear from borehole walls before piezometer installation.

Measurement of Hydraulic Conductivity from Piezometers in Sand and Sandstone

Two factors may have caused the increase in hydraulic conductivity of sand and sandstone in the Milk River basin following the second development operation. Firstly, hydraulic conductivity may have been artificially increased by the removal of particles from the formation around the screen. (The use of a geotextile filter around piezometer screens may help to prevent this phenomenon from occurring).

Development of a cavity in the formation around the screen is not likely to have a noticeable effect on hydraulic conductivity, since the radius of influence of the bail tests was much larger than the borehole diameter. For example, using a borehole diameter of 20 cm rather than the actual 10 cm diameter in bail-test calculations had no effect on hydraulic conductivity values calculated for the Milk River sandstone.

It is more probable that the second development reduced borehole smear, or

removed silt and clay particles which were partially clogging the screen. Therefore, the second hydraulic conductivity value is probably more representative of true hydraulic conductivity.

Slow Recovery to Equilibrium

The hydraulic conductivity (from bail tests) of sand, shallow till and the Milk River Sandstone indicate that they should recover to equilibrium water levels quite quickly after bailing. Extended tail-outs on recovery curves have been encountered at other locations (McKay, Personal Communication). It is probable that hydraulic conductivities decrease with distance away from these piezometers, resulting in a slower response time as water is drawn from greater distances. This is consistent with the fact that buried sand lenses in the TID are probably of limited extent. It is also probable that the Milk River Sandstone is quite heterogeneous.

Water Level Response to Piezometer Development

Slight water-level jumps in the Milk River sandstone following the second piezometer development may have been caused by the removal of silt and clay particles from screens. This explanation is consistent with the universal increase in hydraulic conductivity following the development.

In cases where water-levels rise abruptly by large amounts, such as site 1811 in the TID, it is probable that either the screens were severely clogged, or the bentonite seals above the screened intervals were damaged. This can happen when too much air or water pressure is applied through the screen during development. When piezometer seals are damaged or improperly installed, water levels reach equilibrium with geologic units at shallower depths. Seal-damage is most obvious when it occurs in deep piezometers, whose equilibrium water-levels are much lower than those in shallower deposits. Damaged or improper seals should be suspected on shallower piezometers when water levels do not change with depth.

It is not known when the water levels rose in bedrock in the BRID, due to the ten-year data gap. Similar jumps occurred in bedrock in the Milk River Basin following the second piezometer development, but piezometers in the BRID were not developed between the 1980 and 1990 readings. It is possible that the natural flow of groundwater through the screen gradually reduced borehole smear or clogging particles. It is also possible that the jumps reflect true increases in water pressure (Rodvang 1993b).

CONCLUSIONS AND RECOMMENDATIONS

The following recommendations may help to improve the quality of routine groundwater data.

1. It is very difficult to completely remove drilling or flushing water from a formation. Therefore, water should not be used to flush contamination from groundwater installations, and the use of drilling water should be minimized. If contamination must be removed, compressed nitrogen should be used. If water must be used for drilling or flushing, the installation should be pumped extensively immediately after installation or flushing. Monitoring of electrical conductivity during bailing can indicate when chemistry has stabilized.

2. When a range of hydraulic conductivity values are obtained from bail tests in till, the maximum value should be used to represent bulk hydraulic conductivity.

3. Piezometers in till and bedrock should be installed in a manner which produces minimal borehole smear, which can restrict the movement of water through the screened interval. A downhole device to remove smear should be developed for use on boreholes prior to piezometer installation.

4. Piezometers should be thoroughly pumped following installation, in order to reduce the effects which borehole disturbance may have on hydraulic conductivity and water levels. Development should be done by surging with a Waterra pump, or forcing compressed nitrogen down the hole, rather than by adding water. Minimal air pressure should be used when flushing piezometers, as high pressures may damage the bentonite seals above the screened intervals.

5. The hydraulic conductivity of a formation measured from a piezometer may be artificially high if large amounts of the surrounding formation are removed during pumping. Pumping should be minimized if large amounts of formation material are being drawn through the screen. The use of a geotextile filter around the screen in sandy formations may prevent this from occurring.

6. Careful notes should be taken during all field operations, so that potential anomalies can be assessed.

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A METHOD FOR DETERMINING SATURATED PASTE EQUIVALENT ELECTRICAL CONDUCTIVITIES FROM EM-38 READINGS

D. Wentz, B. Read and C. Livergood[1]

INTRODUCTION

The Conservation and Development Branch is involved in a program of automated soils mapping for the purpose of assessing dryland salinity. The program employs electromagnetic (inductive) techniques to determine soil conductivity using and EM-38 meter. The resulting product aids the investigator in defining recharge and discharge areas which provides a basis for making vegetative control recommendations.

A major aspect of the EM program is the transfer of the mapping technology to field staff from other agencies. This knowledge allows them to conduct independent investigations and to make recommendations for salinity reclamation and control. In order to properly use and understand the values generated by the EM program, it was necessary to develop a system which would rapidly convert EM values into a standard salinity measurement, that is, a saturated paste EC. Furthermore, crop salt tolerance is based on saturated paste EC. If cropping recommendations are to be made based on values derived from EM surveys, it is essential to have these values in a saturated paste format. The development of an EM to saturated paste conversion system is the intent of this project.

METHODS

The first step in developing an EC_a (EM), EC_e (sat. paste) relationship is to conduct an EM-38 grid, from which a set of EM values are obtained. A number of factors influence EM readings, most significantly, soil temperature, moisture and texture. The gridding program is capable of temperature correcting all EM values to 25°C, so that this variable is not critical when mapping. However, it is important to grid only areas within a field which are homogeneous with regard to soil moisture and texture. Generally, these conditions within either the recharge or discharge area are similar. If significant variability occurs, the region exhibiting the variability must be considered separately.

During the EM mapping operation, sites are flagged within the grid area which cover the range of EM values encountered. This is possible since the EM values are displayed on the computer screen for the operator to view as the grid is being conducted. For example, if EM readings ranged from 50-250, flags could be placed at locations where the EM meter read 50, 100, 150, 200 and 250. At each flagged site, the soil should be sampled to a depth of 150 cm and then analyzed for saturated paste EC.

The EM-38 reads to a depth of about 150 cm. Seventy percent of its readings are derived from the top 90 cm with the remaining 30% coming from the bottom 60 cm. As such, it was thought that the saturated paste values should be depth weighted. Regressions performed comparing weighted and non-weighted values against EM-38 readings showed similar coefficients (r^2=0.95, weighted; r^2=0.96, non-weighted). This similarity suggests that non-weighted saturated paste values

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need only be used. Similarly, regression analysis using temperature corrected and non-temperature corrected EM readings versus saturated paste EC yielded almost identical correlation coefficients, eliminating the need to temperature correct field data.

In the development stages of this curve prediction technique, a best-fit curve was plotted to fit the entire range of paired values. When testing the technique, it became apparent that one curve was not always adequate to accurately predict saturated paste equivalent values along the entire length of the curve. When viewing the overall point scatter, two distinct groups of data were evident; that is, those points based on EM values lower than 120 and on EM values higher than 120. Correlation coefficients determined from curves plotted using all data pairs were much lower than those calculated from linear functions plotted using the grouped data. The division at 120 is an arbitrary point specific to the site from which the data were collected. In this case, data pairs happen to fall into groups above and below this value. Plotted points from other fields with different salinity and moisture levels may exhibit different groupings or in fact none at all.

To produce the curves, xy scatter diagrams are constructed for each EM range, with EM values (derived from gridding) on the x-axis and the corresponding saturated paste EC values on the y-axis. The r^2 and p values are determined, a linear curve is plotted and each curve equation is recorded with the appropriate "a" and "b" values (Figures 1 and 2).

The data collected from gridding are stored in a file in a three column x, y, z format with x and y being the directional coordinates and z being the EM data. Once the equations are developed for a specific field they can be entered into the gridding program. When mapping the same area at a future date it will be possible to correct incoming "z" values to a saturated paste equivalent EC, giving a fourth or z1 column. The resulting contour maps can then be constructed from either uncorrected (z) or corrected (z1) data.

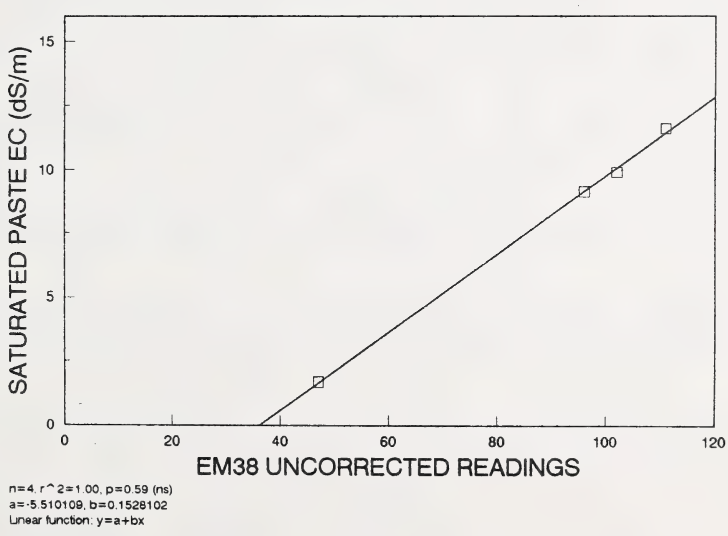

Figure 1. The relationship between low range EM-38 readings and saturated paste EC

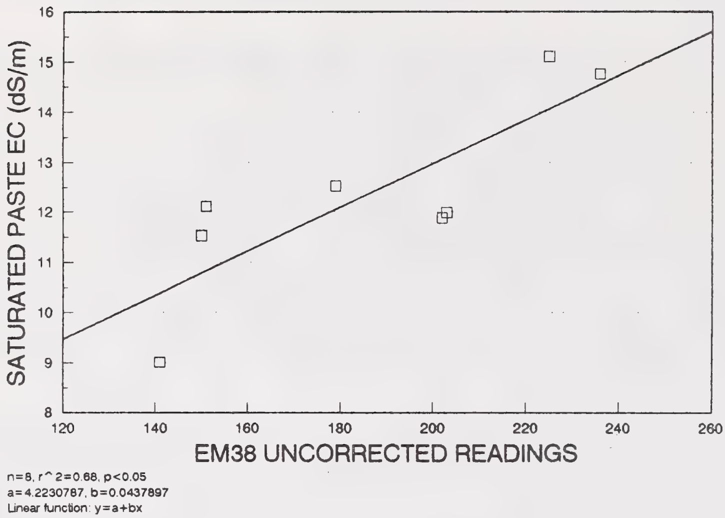

Figure 2. The relationship between high range EM-38 readings and saturated paste EC

RESULTS

A research site in the Crossfield, Alberta area, where routine EM mapping was taking place (SE 26-28-28-W4) was selected to develop and test this method. Gridding was confined predominantly to the saline portion of the field, but extended outside sufficiently to provide a wider range of EM readings with which to work. Gravimetric soil moisture ranged from 18-30%. Soil texture was uniformly a loam to a clay loam. Saturated paste EC from all sample sites and depths ranged from 0.82-18.20 dS/m. The entire test area comprised about 5 ha.

The number of sample holes required to develop the conversion curves was based on the sampling and analysis time available, and on the range of EM readings within the test area. In this instance, twelve holes were sampled with an EM range of 41-236, resulting in a sample hole for about every 16 EM units.

Once the curves are developed, they can be used as a predictive tool to determine EC from EM-38 readings. More specifically, if knowledge of saturated paste equivalent EC is required from an EM reading, it can be approximated from the curve. It must be stressed that curves developed using this technique are only valid for the area from which sampling was performed.

The samples used to develop the curve were tabulated to compare laboratory determined saturated paste EC with saturated paste equivalent EC as calculated using the curve equation. Electrical conductivities were very similar, especially at the lower EM range, with small variations occurring at the higher range (Tables 1 and 2). Variations are largely due to the moderate range of soil moisture (18-30%) in which the samples were collected. Moisture is a major factor influencing conductivity. Data collection within a more narrow range of soil moisture would likely have resulted in only a single conversion curve being required.

CONCLUSION

The ability to rapidly determine approximate saturated paste equivalent EC from EM readings without soil moisture, texture or temperature compensation, can be accomplished using the method described. The benefits of this procedure are realized in reduced time and labor resulting from the small set of samples required. The development of site specific curve equations and their use during subsequent soil mapping operations, allows for the determination of saturated paste equivalent EC in the field. In this instance, the curve prediction technique is able to predict saturated paste equivalent EC within 1 dS/m. The production of salinity maps using values which equate to standard salinity measurement units is also possible. When making cropping recommendations for the vegetative control of dryland salinity, spot EM-38 readings can be readily converted into the same terms as which crop salt tolerance is based.

ACKNOWLEDGEMENTS

Data used to develop the curve prediction technique was collected within the framework of the National Soil Conservation Program, Salinity Assessment Monitoring and Prediction System.

EM-38 READING (uncorrected)	LABORATORY DETERMINED SATURATED PASTE EC (dS/m)	CALCULATED SATURATED PASTE EQUIVALENT EC (dS/m)
141	9.01	10.40
150	11.53	10.79
151	12.11	10.84
179	12.52	12.06
202	11.88	13.07
203	11.99	13.11
225	15.10	14.08
236	14.76	14.56

Table 1. A comparison of saturated paste EC as determined in a laboratory and as predicted from the curve equation, EM range 120+

EM-38 READING (uncorrected)	LABORATORY DETERMINED SATURATED PASTE EC (dS/m)	CALCULATED SATURATED PASTE EQUIVALENT EC (dS/m)
47	1.70	1.67
960	9.14	9.16
102	9.91	10.08
111	11.61	11.45

Table 2. A comparison of saturated paste EC as determined in a laboratory and as predicted from the curve equation, EM range 0-120

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A COMPARISON OF SOIL MOISTURE LEVELS AS DETERMINED BY THE NEUTRON SCATTER TECHNIQUE USING DIFFERENT COUNT RATES

D. Wentz and B. Read[1]

INTRODUCTION

The neutron scatter technique is an accurate, reliable and reproducible method of determining soil moisture content. Permanent installations of neutron probe access tubes can be read over long periods of time to determine site specific soil moisture levels and/or the relative change. The standard time interval (count rate) over which thermalized or slow neutrons are counted in order to determine soil moisture, is generally accepted to be one minute (64 seconds for Campbell gauges and 60 seconds for Troxler gauges). In projects where a large number of tubes are installed and readings are taken at small increments to deep depths, the time spent at each location can be lengthy. If lesser count rates could be used, while maintaining accuracy similar to that achieved with one minute counts, a more efficient use of time would be accomplished. A project was conducted to determine if this is possible.

METHODS

A number of existing research projects in southern and south central Alberta, where permanent installations of access tubes were located, were selected for this study. This provided a range of soil moisture and texture from which to collect data. At these sites, monitoring of soil moisture using a 64 second count rate was routinely taking place. To provide soil moisture data determined using alternative count rates, moisture was read in conjunction with the 64 second count at 16 and 32 seconds as well. Soil moisture values were read at a variety of depths, ranging from 25 cm to 350 cm. Sampling occurred from May through October, 1992. Crop cover included alfalfa, grasses, cereals and fallow. All moisture was determined as a volume percent using a Campbell Pacific, Model 503, Hydroprobe.

RESULTS

Soil moisture data were compiled into two groups for analysis, that is volume percent determined from 16 second and from 32 second count rates. Each group was compared with the standard 64 second count rate moisture values using regression analysis in order to describe the relationship between each pair of variables. In each case there were 856 data pairs. Scatter diagrams showing the plotted data pairs are presented (Figure 1). The r^2 determined from each comparison was 1.00, indicating a very strong x, y relationship. The probability in each instance as determined by t test analysis was less than 0.05. This is evidence of a significant regression/correlation.

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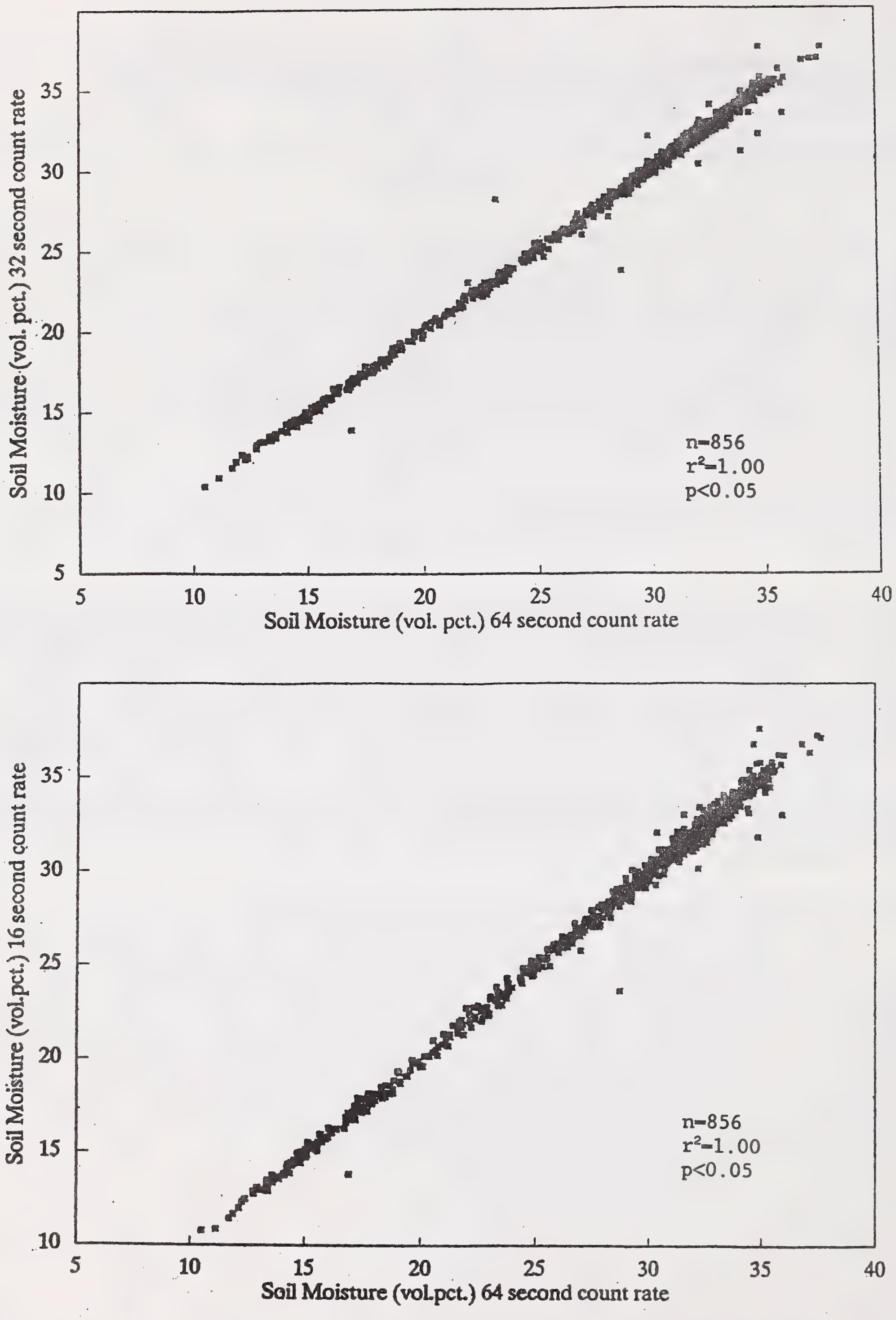

Figure 1. A comparison of soil moisture determined by 16 and 32 second count rates versus the 64 second rate

CONCLUSION

Soil moisture values determined by the neutron scatter technique are essentially identical whether read using 16, 32 or 64 second count rates. High correlation coefficients and significant probabilities, calculated from a large and diverse sample set bear out this fact. For rapid determination of soil moisture, a 16 second count rate can be used with no apparent loss of accuracy.

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PEAT SOIL TEMPERATURE MONITORING AT THE OLTHUIS FARM, 1989 TO 1992

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INTRODUCTION

Peat soils are found on a number of farms in the North West Region. Production of grain crops, primarily barley, on peat soils has met with limited success. A short growing season and nutrient deficiencies have been proposed as the prime causes for production problems with grain crops grown on peat soils in the region.

Farmers in the region have tried a variety of methods to overcome the problems of farming peat soils. One solution proposed was deep plowing. One of the reasons farmers give for deep plowing peat soils is they want them to warm-up faster in the spring. There is justification for this occurring on the basis of what is known about the physical properties of different soils and their effect on heat transfer. It has been observed that peat soils are slow to warm in the spring and that mineral soils warm more quickly. Deep plowing peat soils and mixing with the mineral subsoil is seen as a means of obtaining a soil with more desirable properties.

An examination of the literature revealed little or no field data in Canada to indicate how deep plowing would change the thermal regime. The peat mixing trial was recommended as a way to investigate the merits of various options proposed for mixing or layering peat and mineral soils. A project proposal was submitted to the On-Farm Demonstration Program of Farming for the Future. The project was approved and the study commenced in the spring of 1990.

METHODS

The study site was located at the Olthuis farm east of Neerlandia. Soil temperature was monitored in five different plots:

A - 75% peat soil, 25% mineral soil mix
B - 12" layer of mineral soil over peat soil
C - 6" layer of mineral soil over peat soil
D - control (untreated peat soil)
E - 80% peat soil, 20% mineral soil mix.

A microprocessor based, battery operated CR10 datalogger, manufactured by Campbell Scientific, with suitable eaternal sensors, was used to measure and record air and soil temperatures and precipitation. The data was retrieved at

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intervals varying from a few weeks to a few months. Data logging started on June 19, 1989. The last available record was August 22, 1992.

The data was analyzed in Edmonton, on an IBM PS/2 Model 80 personal computer. Data manipulation, quality control and analysis was done using primarily SAS PC (Statistical Analysis System) software, version 6.04, under DOS version 5.0. All plots were done using SAS/GRAPH software, on a Hewlett-Packard HP7475A graphic plotter. Campbell Scientific PC208 SPLIT software was used to do initial formatting. The quality control procedure consisted of several range checks performed on the recorded data values. All out of range values were set to "missing" for the purpose of further analysis.

The daily mean air temperature and the soil temperature at 3 depths (10, 20 and 50 cm) for the years 1989 to 1992 have been plotted and compared. To do a detailed examination of the effect of mixing peat and mineral soils on spring soil temperature, the daily mean temperature values for the period of April 1 to June 30 were plotted for the 10 and 20 cm depth. They were examined to select intervals of steady soil temperature increase for linear regression analysis. The purpose of the regression analysis was to:

i) determine the slope of the regression line, which gives the reciprocal of warming rate, in days per degree Celsius,
ii) determine the zero intercept, which is the thaw date, and
iii) calculate the sowing date, estimated as the date, when the soil reached 5 deg.C.

RESULTS

Soil thawing dates and warming rates

The data shows large differences between 1990 and 1991 in both the thawing date and soil warming rate. Thawing occured 9 to 11 days earlier in 1991 than in 1990 at the 10 cm depth and typically 5 to 20 days earlier at the 20 cm depth. The only exception was plot B at 20 cm depth, that thawed in both years on the same date. The warming rate was 3.3 to 4.6 times higher in 1991 than in 1990 at the 10 cm depth and 1.9 to 2.5 times higher at the 20 cm depth for all treated plots. Only the control plot warmed up faster in 1990 than in 1991: during the selected period of regression analysis in 1991 the control plot (D) was barely heating up.

The reciprocal of warming rate varies from about 0.9 to 5 days per degree Celsius for all treated plots, and from about 4 to 28 days per degree Celsius for the control plot. This parameter has significant practical implications in providing a useful reference value which can be used for scheduling spring planting. For example, if a manual reading of soil temperature at 10 cm depth is 2 deg.C and seeding would take place when the soil reaches 5 deg.C, then 3 deg C of warming is needed. The number of days needed to reach the desired temperature can be calculated by multiplying the warming needed by the warming rate:

$$3 \text{ deg.C} \times 3.9 \text{ days/deg.C} = 11.7 \text{ days.}$$

Differences in thawing dates between the treated plots and the control plot show, that all treated plots thawed substantially earlier than the control plot. In 1990 the gain was about 7.5 to 8.5 days at 10 cm depth and 25 to 26 days at 20 cm depth. In 1991 the gain was smaller: about 5.5 to 8.5 days at 10 cm depth and 7 to 15 days at 20 cm depth.

Sowing dates (dates of reaching 5 deg. Celsius)

The date of thawing is of little practical use, since the date of planting

is the important one to consider. Since the rate of warming varies among plots and years, the differences at the thaw dates are not representative of the situation when the soil reaches a warmer temperature. The value of 5 deg.C was chosen as a temperature at which a person wanting to seed early might consider doing so.

Calculated sowing dates are shown in Tables 1 and 2. Gain in sowing date is shown in Tables 3 and 4.

All treatment plots reached 5 degrees Celsius substantially earlier than the control plot. In 1990 the gain was about 9.5 to 11 days at 10 cm depth and 16 to 18 days at 20 cm depth. In 1991 the gain was smaller: about 0.5 to 8 days at 10 cm depth and 4.5 to 7 days at 20 cm depth.

TABLE 1. OLTHUIS SOWING DATE FOR 10 cm DEPTH
(Date at which temperature reached 5 degrees Celsius)

	PLOT					
Year	A	B	C	D	E	Date Range
1990	MAY 04	MAY 03	MAY 03	MAY 13	MAY 03	APR 29 - MAY 05
1991	MAY 02	APR 24	APR 25		APR 26	APR 03 - APR 14
				MAY 03		APR 11 - APR 22

Note: date range is the dates used for regression analysis.

TABLE 2. OLTHUIS SOWING DATE FOR 20 cm DEPTH
(Date at which temperature reached 5 degrees Celsius)

	PLOT					
Year	A	B	C	D	E	Date Range
1990	.	MAY 13	MAY 11	MAY 30	MAY 13	MAY 08 - MAY 30
1991	.	MAY 10	MAY 08		MAY 07	MAY 07 - MAY 12
				MAY 14		MAY 08 - MAY 13

Plots: A - 75% peat soil, 25% mineral soil mix
B - 12" layer of mineral soil over peat soil
C - 6" layer of mineral soil over peat soil
D - control (untreated peat soil)
E - 80% peat soil, 20% mineral soil mix.

. - missing data

TABLE 3. GAIN IN SOWING DATE AT 10 cm DEPTH AT OLTHUIS: NO. OF DAYS COMPARED TO THE CONTROL PLOT (D)

	PLOT				
Year	A	B	C	D	E
1990	9.53 (4)	10.43 (3)	10.94 (1)	0.00 (5)	10.78 (2)
1991	0.58 (4)	8.39 (1)	7.69 (2)	0.00 (5)	6.98 (3)

Note: Rank given in brackets.

TABLE 4. GAIN IN SOWING DATE AT 20 cm DEPTH AT OLTHUIS: NO. OF DAYS COMPARED TO THE CONTROL PLOT (D)

	PLOT				
Year	A	B	C	D	E
1990	. .	16.12 (3)	18.33 (1)	0.00 (4)	16.87 (2)
1991	. .	4.50 (3)	6.54 (2)	0.00 (4)	7.27 (1)

Plots: A - 75% peat soil, 25% mineral soil mix
B - 12" layer of mineral soil over peat soil
C - 6" layer of mineral soil over peat soil
D - control (untreated peat soil)
E - 80% peat soil, 20% mineral soil mix.

Note: Ranking given in brackets.
. - missing data

CONCLUSIONS

The treatment plots were warmer than the control, as seen in differences in both thawing date and sowing date. Plots B (12" layer of mineral soil over peat soil), C (6" layer of mineral soil over peat soil), and E (80% peat soil, 20% mineral soil mix) are consistently better, than plot A (75% peat soil, 25% mineral soil mix).

The ranking varies between the two years of observation. The data is not sufficient to determine the single best soil amendment to improve warming. However, each of the amendments was successful in warming the soil earlier. In order to apply statistical methods, more data is needed.

The effect of faster warming on crop performance has not been the subject of this study. Faster soil warming should act to improve germination and probably yield. The potential for increase in yield would be sufficient to justify the cost of peat soil amendment based on a deep plowing study at the Devries and Marks sites (Farming For the Future report, OFD 87-F003-5).

TIMING BEE EMERGENCE TO COINCIDE WITH OPTIMUM ALFALFA PLANT FLOWERING STAGE

Gregory Snaith[1] and Dave McKenzie[2]

INTRODUCTION

Alfalfa must be cross-pollinated to obtain top yields. For this purpose, the leaf-cutter bee is used. This bee requires a 21 day incubation period for the overwintered pre-pupae to hatch. The timing of the hatch must ensure that there will be an adequate supply of alfalfa flowers or else the bees will leave the field in search of food. On the other hand, the grower would like to take advantage of the first alfalfa flowers, which are known to produce the best seeds.

Traditionally, growers have used either a calendar date or waited until they observed the first flower in the field as a method of determining when to start the incubation process. This project was initiated in an attempt to find a better method for making this determination.

METHODS

Once a week, a technician picked 50 stems at random from each of 20 fields. These stems were sorted into 4 groups: no buds, bud swell (the bud can be felt by gently squeezing the plant tip between thumb and forefinger), buds visible (the bud can be readily seen), and flowers visible (color can be readily detected). The procedure was continued until the field was beyond the 60% bloom stage (more than 30 stems had flowers visible). The correct timing for incubation was determined by observing the optimum plant stage for bee introduction and subtracting 21 days (the time required for pupation).

RESULTS AND DISCUSSION

In order to have the bees in the field at the 50-60% bloom stage, incubation should commence when 12 of 50 stems (24%) are in the no bud stage (plus or minus 3 stems); 26 stems (52%) are in the bud swell stage (plus or minus 3 stems); and 12 stems (24%) are in the bud visible stage (plus or minus 5 stems). Over the past 3 years, this has been June 2, plus or minus 3.7 days. The procedure recommended for finding this day is the check the field during the last week of May. Pick 50 stems and keep only those which fit into the no bud or the bud visible stage. By knowing that the no buds are decreasing at the rate of one per day, while the buds visible are increasing at about the same rate (figure 1) and that incubation should commence when the two stages are equal, a simple calculation (half the difference between the 2 counts) reveals the incubation day.

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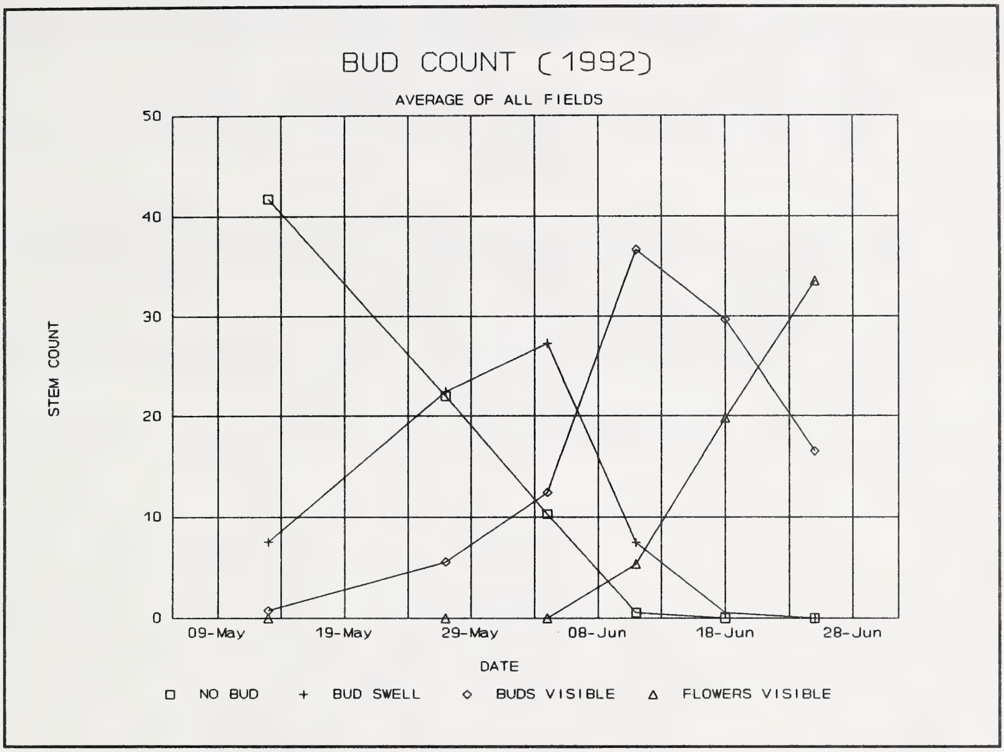

Figure 1: Raceme development (1992)

SUMMARY

It may be possible to use this data to accurately predict incubation date. A further possibility is to use weather data supplied by Conservation and Development Branch to obtain a relationship between crop development stage and cumulative degree days. However, problems exist in obtaining this data on a daily or weekly basis. The degree day calculation would have to be made manually from data received from the Alberta Special Crops and Horticultural Research Centre's weather station.

FORAGE PRODUCTION ON IRRIGATED CHERNOZEMIC AND SOLONETZIC SOILS IN THE BERRY CREEK BASIN (YEAR TWO-1992)

G.M. Greenlee, T.M. Peters, P.D. Lund and D.R. Bennett[1]

INTRODUCTION

The objectives of this four-year study in the Berry Creek Basin are:

1) To determine the forage production capability of two Solonetzic and two Chernozemic soil associations under three levels of irrigation.
2) To assess changes in soil salinity and sodicity in these soils resulting from the three different levels of irrigation.
3) To evaluate the irrigation suitability of the irrigated Solonetzic soils in light of the irrigation management regimes implemented.

This progress report contains a brief summary of results from monitoring conducted in 1992. A summary of results from 1991 monitoring is given in Bennett et al. (1992).

METHODS

Background

Four study sites in the Berry Creek Basin of east-central Alberta were selected for this project in the summer of 1990. Two study sites consist of dominantly Solonetzic soils (Weich site near Hanna and Blair site near Sheerness) and the other two sites (McNiven and Sunstrum near Cessford) have mainly Brown Chernozemic soils. The Solonetzic sites are adjacent to relatively large Ducks Unlimited reservoirs, and the Chernozemic sites are adjacent to Berry Creek. Each study site consists of a rectangular field approximately 55 m wide by 340 m long. Four seasonal treatments, representing three target levels of irrigation-200, 300 and 400 mm, and a dryland control-were replicated three times within each study site. Each replicate of each treatment represents a plot, each plot is approximately 55 m long by 18 m wide and each study site has 12 plots. The plots are separated by 9-m wide buffer strips.

Ten soil profiles per plot were characterized and sampled in the fall of 1990 along two parallel transects (five soil profiles per transect) situated 5 m from the side of each plot and starting 10.4 m from the end of the plot. Each profile was sampled according to horizons, with representative samples taken from the A and B horizons and from the upper and lower C horizons to a depth of 1.2 m. Soil samples were analyzed for pH, electrical conductivity (ECe) and soluble cations of the saturation paste extract using standard analytical techniques (Rhoades 1982), and the sodium adsorption ratio (SAR) was calculated.

One water table well and two 1.5 m long neutron probe access tubes were placed within each plot to monitor shallow water table fluctuations and soil moisture content in response to irrigation events and precipitation. A datalogger and tipping-bucket rain gauge were used to record natural precipitation at each study site.

Plot mean values for crop yield were analyzed using an analysis of variance statistical model and a protected least significant difference test. A split-plot analysis of variance, with time as the split, and protected least significant difference test were conducted for each soil chemical parameter to

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determine whether significant changes in ECe and SAR had occurred from 1990 to 1992 within each sampling depth at each site. Box's conservative F-test (Box 1954) was used to test the significance of the year and year by treatment effects since years could not be randomized in this study. Tukey's studentized range test was used to compare mean values for each treatment from 1990 to 1992 when the year by treatment interaction was significant in the analysis of variance.

Cropping, Irrigation and Monitoring

Initial site preparation and cropping in 1991 were described by Bennett et al. (1992). Fertilizer was deep-banded into barley stubble at a rate of 336 kg ha^{-1} of 11-51-0 in the spring of 1992. Beaver alfalfa seed was inoculated with Rhizobium and direct-seeded at a rate of 12 kg ha^{-1} with a zero till truax drill. The alfalfa plots at each site were sprayed with sethoxydim (poast) in June at a rate of 19 L ha^{-1} to control volunteer barley. A solid-set irrigation system was installed on each irrigated plot and irrigation water was applied at a rate of 10 mm h^{-1} in increments of 20, 30 and 40 mm on the 200, 300 and 400 mm treatments, respectively. Irrigation events in 1992 ranged from only three at the Weich site to seven and one-half at the McNiven site due to the abnormally high levels of natural precipitation. This resulted in total applications ranging from 71, 122 and 158 mm for the 200, 300 and 400 mm treatments, respectively, at the Weich site to 172, 270 and 339 mm for the 200, 300 and 400 mm treatments, respectively, at the McNiven site (Figure 1). These were actual application amounts measured by rain gauges situated in the irrigated plots.

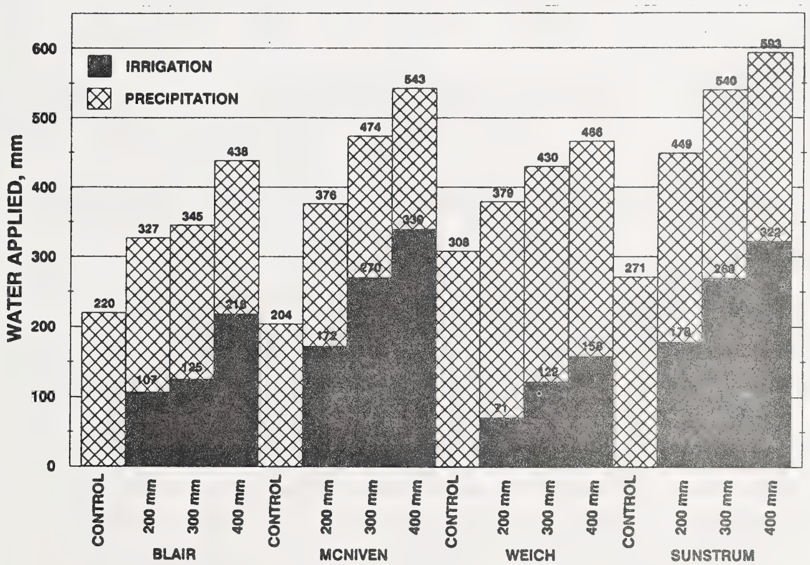

Figure 1. Total water applied during the 1992 growing season at the four study sites.

Alfalfa yields were determined by sampling alfalfa in one cut during early September at the ten locations within each plot where soils were sampled. Soil samples were collected again in the fall of 1992 from the same ten locations within each plot.

PRELIMINARY RESULTS AND DISCUSSION

Site Characteristics

Relative percentages of Solonetzic and Chernozemic soils that occur at each study site were indicated by Bennett et al. (1992). Statistical analyses of 1990 soil samples to assess the uniformity of treatments at each study site indicated that significant differences between treatments were not detected for any soil chemical parameter except for pH of the B horizon. The conclusion was that initial soil characteristics were reasonably uniform at each study site prior to irrigation.

Alfalfa Yield and Water Applied

The significance of differences in total dry matter (TDM) yield between treatments in 1992 (Table 1) indicates that a minimal response to irrigation was observed on the two Solonetzic study sites. No significant differences were observed between treatments at the Weich site, and significant differences were observed at the Blair site on the 200 mm treatment and between the 200 mm and 400 mm treatments. Abnormally high amounts of natural precipitation reduced the need for irrigation, and masked the treatment effects. The Weich site received 308 mm of precipitation, as compared to 220 mm at the Blair site, 204 mm at the McNiven site and 271 mm at the Sunstrum site.

Significant differences in TDM yield between the irrigation treatments and the dryland control, and between the 200 mm and 300 mm treatments were detected at both Chernozemic study sites. Yields were highest in the 400 mm treatments, but the differences between the 300 mm and 400 mm treatments were not significant.

Table 1. Comparison of mean alfalfa yield from each treatment in 1992

	Treatment[z]				
Site	Control	200 mm	300 mm	400 mm	Probability
Total Dry Matter, t ha^{-1}					
Weich	0.97 a	0.85 a	1.14 a	0.71 a	$p < 0.01$
Blair	0.44 a	1.14 b	1.54 bc	1.80 c	$p < 0.05$
McNiven	0.08 a	1.50 b	2.37 c	2.73 c	$p < 0.05$
Sunstrum	0.00 a	0.66 b	1.69 c	2.05 c	$p < 0.01$

[z] Values for the treatments at each site followed by the same letter are not significantly different at $p < 0.01$ or $p < 0.05$, as determined by a protected least significant difference test.

Changes in Soil Salinity and Sodicity

Statistically significant differences in soil salinity and sodicity were evident within the A horizon of soils at each study site from 1990 to 1992 (Tables 2 and 3). A significant increase in soil salinity and sodicity was detected in the A horizon at the Weich site from 1990 to 1992 (Table 2), however, no significant differences were observed between the irrigation treatments and the dryland control (Table 3). A significant year by treatment interaction was detected in the A horizon of soils at the Blair, McNiven and

Sunstrum study sites, and in the B horizon of soils at the McNiven site (Figure 2). Salinity and sodicity in the A horizon of soils in the irrigation treatments at the Blair, McNiven and Sunstrum sites and in the B horizon of soils at the McNiven site have generally increased from 1990 to 1992, however, some of these differences were not statistically significant (Figure 2).

A significant decrease in soil salinity was detected in the B horizon of soils at the Weich and Blair sites from 1990 to 1992 (Table 2). Significant changes in soil salinity and sodicity in the C1 and C2 horizons of soils from

Table 2. Comparison of soil salinity and sodicity at the four study sites from 1990 to 1992[z]

Site	Horizon	EC, dS m^{-1} 1990	EC, dS m^{-1} 1991	EC, dS m^{-1} 1992	SAR 1990	SAR 1991	SAR 1992
Weich	A	0.65b	0.75a	0.79a	4.06b	4.80a	4.60a
	B	2.69a	1.87c	2.14b	10.50a	10.37a	10.32a
	C1	5.87a	5.40a	5.28a	11.14a	11.67a	10.42b
	C2	7.53a	6.91b	6.79b	12.70a	12.33a	11.81b
Blair	A[y]	0.48	0.74	0.75	3.27	4.55	5.08
	B	3.33a	2.24b	2.48b	11.80a	11.54a	11.03a
	C1	6.39a	5.97ab	5.60b	12.48a	12.61a	11.71a
	C2	7.85a	7.25a	6.96a	14.20a	14.24a	13.16b
McNiven	A[y]	0.26	0.70	0.51	0.30	0.96	1.65
	B[y]	0.27	0.39	0.55	0.59	0.68	0.84
	C1	0.53a	0.60a	0.68a	1.37a	1.37a	1.18a
	C2	1.25a	1.05a	1.18a	1.87a	1.98a	1.69b
Sunstrum	A[y]	0.27	0.68	0.51	0.30	0.71	1.19
	B	0.42a	0.53a	0.52a	0.55a	0.61a	0.64a
	C1	0.62b	0.91a	0.82a	1.40a	1.42a	1.35a
	C2	1.05b	1.39a	1.16b	2.77a	2.49a	2.39a

[z] Where annual mean salinity and sodicity values for each horizon at each site followed by the same letter are not significantly different at $p < 0.05$.
[y] Year by treatment interaction was significant at $p < 0.05$, see Figure 2.

Table 3. Comparison of soil salinity and sodicity between treatments at the four study sites[z]

Site	Horizon	EC,dS m^{-1} Control	EC,dS m^{-1} 200 mm	EC,dS m^{-1} 300 mm	EC,dS m^{-1} 400 mm	SAR Control	SAR 200 mm	SAR 300 mm	SAR 400 mm
Weich	A	0.68a	0.70a	0.71a	0.84a	3.61a	4.26a	3.95a	6.59a
	B	2.05a	2.16a	2.12a	2.57a	8.86a	10.20a	9.94a	12.94a
	C1	5.03a	5.20a	5.87a	6.00a	9.94a	11.27a	10.48a	12.76a
	C2	7.37a	6.47a	7.00a	7.48a	12.02a	12.19a	11.85a	13.09a
Blair	A[y]	0.55	0.68	0.73	0.65	3.31	4.75	4.24	4.85
	B	3.18a	2.76a	1.98a	2.82a	11.76a	12.21a	9.35a	12.78a
	C1	6.05a	6.41a	4.74a	6.91a	11.50a	13.41a	10.76a	13.60a
	C2	7.10a	7.36a	6.45a	8.71a	12.67a	14.97a	12.55a	15.48a
McNiven	A[y]	0.35	0.54	0.50	0.54	0.31	0.93	1.21	1.28
	B[y]	0.31	0.41	0.46	0.42	0.58	0.66	0.90	0.69
	C1	0.61a	0.62a	0.61a	0.56a	1.16a	1.53a	1.45a	1.11a
	C2	0.87a	1.39a	1.38a	1.04a	1.53a	2.19a	1.81a	1.88a
Sunstrum	A[y]	0.43	0.45	0.50	0.52	0.26	0.70	0.90	1.01
	B	0.45a	0.58a	0.46a	0.46a	0.57a	0.72a	0.55a	0.56a
	C1	0.73b	0.88a	0.75b	0.76b	1.49a	1.76a	1.16a	1.19a
	C2	1.14a	1.44a	1.17a	1.05a	2.83a	3.15a	2.02a	2.29a

[z] Where treatment means for each horizon at each site followed by the same letter are not significantly different at $p < 0.05$.
[y] Year by treatment interaction was significant at $p < 0.05$, see Figure 2.

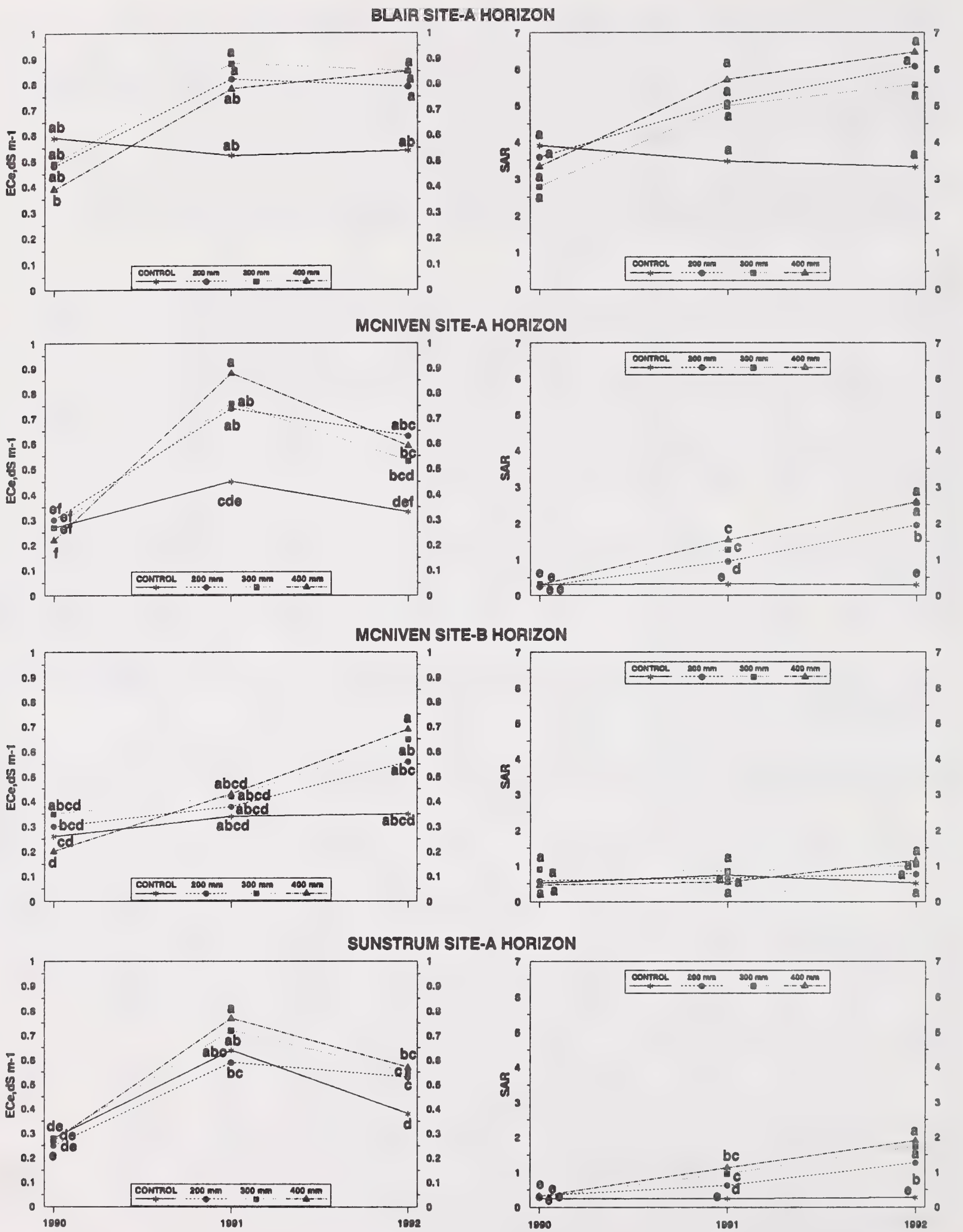

Figure 2. Comparison of soil horizon salinity and sodicity in each treatment at the three study sites which had a significant year by treatment interaction from 1990 to 1992 (mean values for each horizon at each site followed by the same letters are not significantly different at $p < 0.05$).

the different treatments were generally not observed from 1990 to 1992. Increases in soil salinity and sodicity in surface horizons may reflect the new equilibrium being established in the soils due to the irrigation water quality. Irrigation water EC values at the Weich site ranged from about 0.14 to 0.27 dS M^{-1} in 1991 and 0.28 to 0.3 dS m^{-1} in 1992, with SAR values from 1.5 to 2.6 in 1991 and 2.8 to 3.0 in 1992. Irrigation water at the Blair site had EC values from 0.6 to 0.74 dS m^{-1} in 1991 and 0.6 to 0.64 dS m^{-1} in 1992, with SAR values from 3.8 to 4.2 in 1991 and 3.0 to 4.3 in 1992. Berry Creek water, used for irrigating the McNiven and Sunstrum (Chernozemic) sites, had EC values ranging from about 0.45 to 0.67 dS m^{-1} in 1991 and 0.52 to 0.73 dS m^{-1} in 1992, with SAR values from 1.7 to 2.7 in 1991 and 1.6 to 2.4 in 1992. Decreases in soil salinity in the A horizons of soils at the McNiven and Sunstrum sites from 1991 to 1992 may be due to leaching of salts by the abnormally high amounts of natural precipitation, in addition to the irrigation water applied. Additional monitoring is required to verify the trends observed from 1990 to 1992.

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